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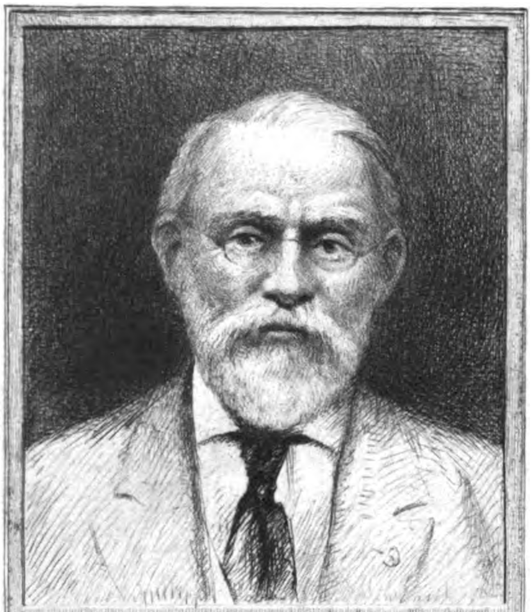

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Union Internationale de Radiotélégraphie Scientifique

International Union of Scientific Radio Telegraphy

U.R.S.I.

RECUEIL DES TRAVAUX

DE
l'Assemblée Générale tenue à Washington
en Octobre 1927

PAPERS

OF THE
General Assembly held in Washington
in October 1927

FASCICULE 1

Mémoires scientifiques
présentés à la séance publique.
(TEXTES ORIGINAUX)

Scientific papers
presented in the public session.
(ORIGINAL TEXTS)

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The existence of more than one ionized layer in the upper atmosphere,

by Profr. E. V. APPLETON, F. R. S.
(Great Britain)

During the past year and a half systematic observations have been made at the Peterborough Research Station on the characteristics of wireless waves deviated by the upper atmosphere. As part of such routine measurements many determinations of the equivalent height of the Kennelly-Heaviside layer have been made, utilizing special transmissions from the National Physical Laboratory and from the stations of the British Broadcasting Corporation. The early summer observations of 1926 showed that the night-line height of this deviating layer (called, for convenience the E layer), for wave-lengths of 400 meters, was usually 90 kilometers to 130 kilometers. During the period 6 October 1926 to May 1927, however, heigths of an entirely different order of magnitude, namely 250 kilometers to 350 kilometers, have been frequently measured during the three hours before dawn.

On such occasions, after the high values have been recorded for two or three hours, a discontinuity in the series of values occurs 20 to 40 minutes before sunrise, and heights of the normal value are again recorded.

The experimental evidence leaves little doubt that on such occasions, in the period before dawn, the ionization in the Kennelly-Heaviside layer (Layer E) has been sufficiently reduced by recombination to permit of its penetration by waves of this frequency. « Reflection », however, takes place at an upper layer (F layer) which is richer in ionization. With the advent of sunrise at a height of 100 kilometers or so, the Kennelly-Heaviside layer (layer E) is formed again and deviation by this layer is suddenly established. The normal fall of its under- boundary proceeds as the more direct solar influence increases the region ionised. As the day further proceeds the experimental results show that another region of ionization (D layer) is formed below the Kennelly-Heaviside layer, which, while causing attenuation of the waves, does not materially affect the height at which they are deviated. Occasionally « reflected » waves are detected from this layer. Its main function is, however, to absorb the waves which are only slightly bent in passing through it, and which are finally deviated by Layer E. It is suggested that layer D is the same as the ozone discovered by Lindemann and Dobson.

* * *

The influence of the earth's magnetic field on wireless transmission (Summary),

by Profr. E. V. APPLETON, F. R. S.
(Great Britain)

The magneto-ionic theory of the propagation of wireless waves in an ionized medium proposed by the writer (*) and by Nichols and Schelleng (**) is extended to the general case of propagation in any direction with respect to the magnetic field. The symbols used have the same significance as those used by H. A. Lorentz (***) except that for free electrons it is shown that we must write $g = \frac{m}{\tau}$ (and not $g = \frac{2m}{\tau}$ as used by Lorentz for bound elctrons). When absorption is neglected the formula for the refractive index reduces to

$$\mu^2 = 1 + \frac{2}{2\alpha - \frac{\gamma_T^2}{1+\alpha} \pm \sqrt{\frac{\gamma_T^2}{(1+\alpha)^2} + 4\gamma_L^2}}$$

where γ_T and γ_L refer to the terms involving the tangential and longitudinal components of the magnetic field respectively. There are thus two waves propagated, in general.

The above formula shows that μ^2 becomes infinite when

$$\alpha^2 = \gamma_L^2 + \left(\frac{\alpha}{1+\alpha}\right)\gamma_T^2$$

so that only when ($\alpha \gg 1$) do we get

$$\alpha^2 = \gamma_L^2 + \gamma_T^2 = \gamma^2$$

and quasi-resonance with the total field. This means that only when the ionization is small

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(*) *Proc. Phys. Soc.*, 37, February 1925.

(**) *Bell Technical Journ.* 4, 215, April 1925.

(***) « *Theory of Electrons* », pp. 139 et seq.

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should critical effects occur for one of the waves at about 200 meters.

The formula further shows that μ^2 becomes zero, indicating possibility of reflection even at vertical incidence on the layer, when

$$1 + \alpha = 0,$$

or

$$1 + \alpha = \pm \gamma$$

relations which involve only the total magnetic field.

The marked absorption in the D layer will act differentially on the two waves which are, in general, transmitted, so that for wave-lengths in the broadcasting band in Europe we may expect only the non-critical ray to reach the ground in appreciable intensity. In this way the results of Meissner, who found no anomalies at 212 meters, may be explained.

* * *

On the influence of Solar activity on Radio Transmission (1),

L. W. AUSTIN and Miss I. J. WYMORE
(Laboratory for Special Radio Transmission Research,
Bureau of Standards, Washington D. C. (U. S. A.)

At the meeting of the American Section of the U. R. S. I. in April, 1927, some curves were shown (2) indicating a relationship between very long wave transatlantic radio reception and solar activity as measured by sunspot numbers and by the values of the solar constant. These curves represented annual averages from 1915 to 1926, and monthly averages from 1922 to 1926. These indicated without much question that there exists a direct correlation between solar activity and daylight signals, when averaged over long periods. Curves were also shown illustrating the correspondence of 27-day periodic averages of sunspots and reception.

G. W. Pickard (3) had previously published a paper using his own observations in the broadcasting band, as well as the observations of others, on very long as well as ultra short wavelengths, in which he produced striking evidence of the dependence of radio phenomena on solar activity. Mr. Pickard's own observations indicated quite positively an inverse relationship between the strength of night signals in the broadcasting band and sunspot numbers, while the ultra short wave night signal material treated by the same methods, indicated a direct correlation. This last conclusion is, however, seemingly not in agreement with a number of observations made by others of weakened ultra short wave night signals at times of great solar and magnetic disturbances.

During the past summer the examination of the long wave observational material at the Bureau of Standards, in connection with sun spots, has been continued. Especial attention is now being given to the correlation of the daily observations, or the averages of a few days at most, rather than to long time averages. It is found in general that daily comparisons of signals and sun spots give too complex curves to be of use. But when they are averaged in five-day periods good results begin to appear. It is also found in the examination of the material that the stations at moderate distances (less than 1,000 km.) when treated in this way give on the whole better correlation with sun spots than more distant stations.

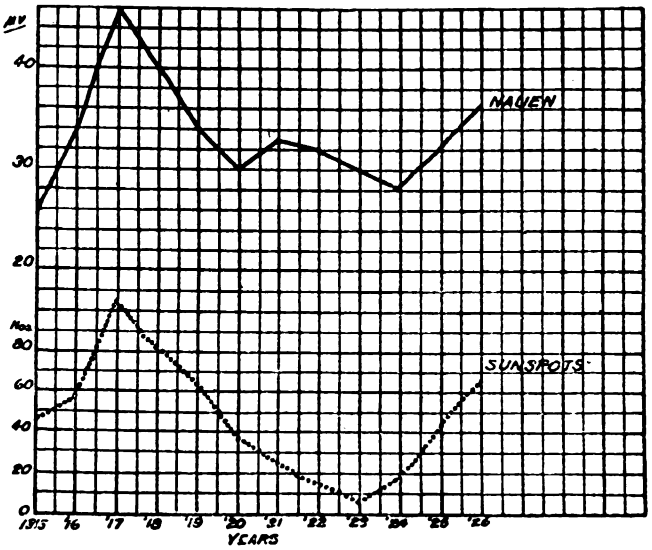

FIG. 1. — Annual Average Signal Intensity of Nauen (AGS), 10 A.M. and Sunspot Numbers.

Since the signal and sunspot curves do not follow each other entirely in detail, it seems probable that there are other factors besides solar activity which contribute to the signal variations. One of these we believe to be temperature which has already been shown (1) to have a strong influence especially in winter on the reception in Washington of the transatlantic stations at New Brunswick and Tuckerton, New Jersey.

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(1) Read at the International meeting of the Union of Scientific Radio Telegraphy in Washington, October 14, 1927.

(2) PROC. I. R. E., vol. XV, p. 825, 1927.

(3) PROC. I. R. E., vol. XV, p. 83, 1927. See also vol. XV, p. 749, 1927.

There also seems to be a tendency for the sunspot and signal curves to shift relatively back and forth in phase as though at times there might be a lag in the appearance of the sun spots in respect to the fundamental solar disturbance producing them, while on the other hand, there often seems to be a delay in the formation of the conditions in the earth's atmosphere which produce the changes in signal strength. At any rate there is no doubt that at times the increase in signal precedes the increase in sun spots, while at other times the reverse seems to be true.

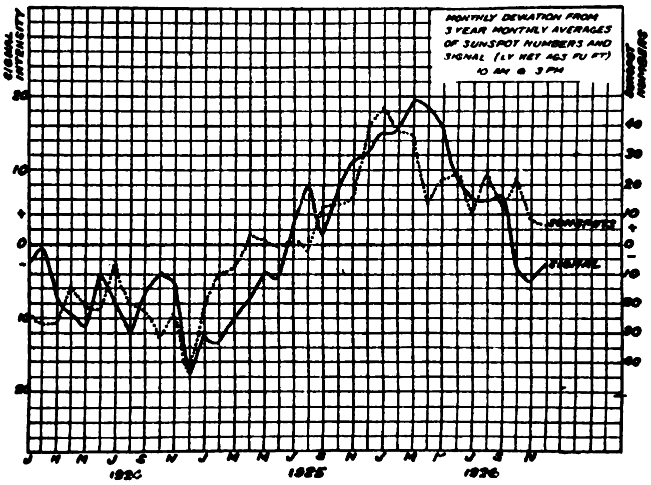

FIG. 2.

Notwithstanding these phase shifts, the frequent similarity of the sunspot and signal curves renders it almost certain that we are dealing with a genuine relationship. On the whole there seems to be about the same degree of correlation between the signals and sun spots as between signals of similar wavelengths received at a given receiving station from two separate transmitting stations. In the following, Figs. 1, 2, and 3 deal with long time comparisons in which the connections between solar activity and radio transmission is believed to be fairly well established, while Figs. 4, 5, 6, and 7 deal with short period (5-day) averages in which the transmission curves are smoothed by the smoothing formula $\frac{a+2b+c}{4}$. This last, without changing the positions of the main maxima and minima, renders the transmission curves more easily comparable with those of the sun spots.

Fig. 1 shows the annual averages of Nauen ($\lambda = 13{,}000$ m.) as received at Washington at 10 A. M. from 1915 to 1926, and the corresponding annual averages of the Wolfer sunspot numbers covering the same period. The signals from 1915 to 1921 were taken by the shunted telephone method and are therefore less accurate than those taken later, but we believe that there can be no doubt that the general course of the curve is correct.

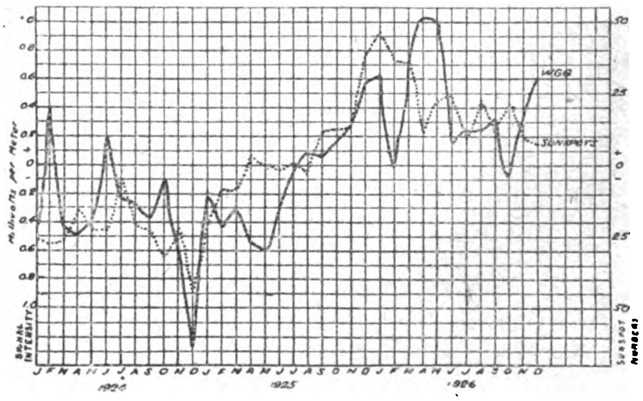

FIG. 3. — Monthly Deviation from 3-Year Monthly Averages of Tuckerton (WGG), 10 A.M. and 3 P.M. (Corrected for Variations in Antenna Current) and Sunspot Numbers, 1924-1926.

Fig. 2 (1) shows the deviations of the individual monthly averages from the three-year monthly averages of five distant stations as compared with the sunspot numbers. It is seen that, while the two curves do not follow each other in detail, in general they rise together during the three years of increasing solar activity. The portion of the figure dealing with the rapid increase of sun spots in the autumn of 1925 is of especial interest.

Fig. 3 shows similar curves for the Radio Corporation of America transatlantic station at

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(1) PROC. I. R. E., vol. XIV, p. 781, 1926.

(1) Figs. 1 and 2 are repeated from PROC. I. R. E., vol. XV, p. 825, 1927.

Tuckerton, N. J. (WGG), only 250 km. from Washington.

As has been said, the degree of correlation between sun spots and signals is comparable with that between two signals received at one point from different transmitting stations. For comparison with the following curves, therefore, Fig. 4 is shown giving the relationship of the five-day averages of Tuckerton, WGG, and Bordeaux LY as received at 10 A. M. during a portion of 1925 at the Bureau of Standards.

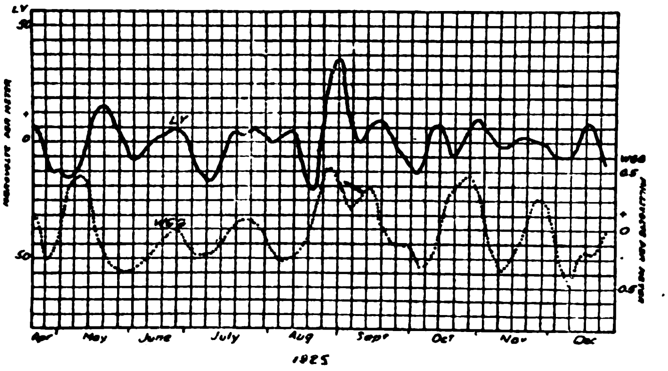

FIG. 4. — Deviation of 5-Day Averages from Monthly Averages of Tuckerton (WGG), 10 A.M. and 3 P.M. and Lafayette (LY), 10 A.M. (1925).

Fig. 5 shows the deviations of the five-day averages of Tuckerton as compared with the five-day averages of the sun spots in 1924. The year 1924 was very near the sunspot minimum.

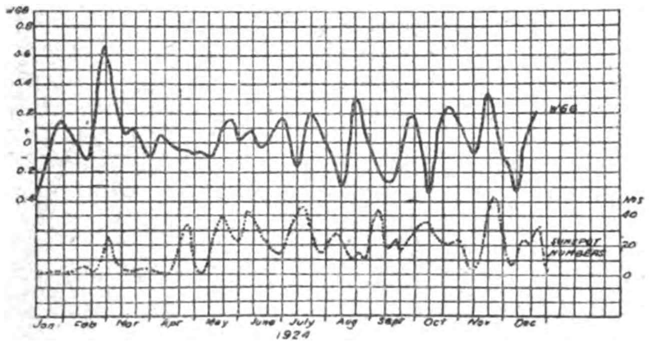

FIG. 5. — Deviation of 5-Day Averages from Monthly Averages of Tuckerton (WGG), 10 A.M. and 3 P.M. and 5-Day Averages of Sunspot Numbers, 1924.

Fig. 6 shows the relationship between the sun spots and the same station between March, 1926 and March, 1927. Here the curves are drawn on a smaller scale than in 1924 on account of the much greater amplitude of the variations both of the sunspot numbers and of the signal intensity. It is at once seen that the degree of correlation of the sunspot numbers and signal seems much better in 1926 and 1927 than during the period of low solar activity in 1924.

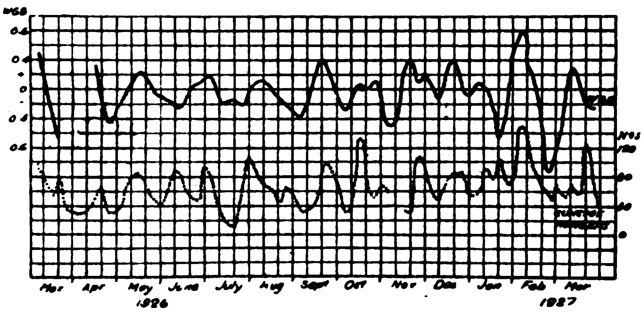

FIG. 6. — Deviation of 5-Day Averages from Monthly Averages of Tuckerton (WGG) and 5-Day Averages of Sunspot Numbers, 1926-1927.

Fig. 7 shows similar curves for the R. C. A. station WSS at Rocky Point, L. I., at a distance of 435 km. from Washington in 1926-27. In addition to the signal and sunspot curves, a curve of the five-day averages of the range of the horizontal intensity of the earth's field as observed at Cheltenham, Maryland, is included.

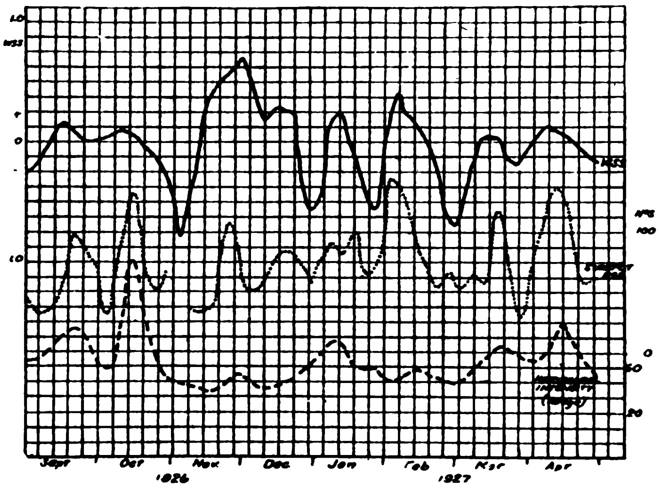

FIG. 7. — Deviation of 5-Day Averages from Monthly Averages of Rocky Point (WSS), 10 A.M. and 3 P.M. and 5-Day Averages of Sunspot Numbers and Horizontal Intensity (Cheltenham), 1926-1927.

The resemblances between these curves are really striking, though we find here also the relative shifts in phase already mentioned between the sunspot numbers and the signal intensity. In some cases the signals evidently lead, while in other cases they lag.

In examining the curves of the five-day

averages, it is evident that while there is little question of a connection between solar activity and radio signal intensity, yet there is a lack of any direct proportionality between the sunspot numbers and signal strength. For it is not by any means always the largest increase in sun spots which corresponds to the largest increase in radio transmission.

Our present knowledge concerning the relation between solar activity and the strength of radio transmission may be briefly summarized as follows :

It seems reasonably certain that long wave daylight signal strength has increased in recent years with the increasing solar activity, when averaged in periods of a month or more, and there is fair evidence that the annual averages of signal intensity have roughly followed the sunspot curve since 1915.

It is also reasonably certain that night transmission in the broadcasting range when averaged in periods of a few days is reduced at times of high sunspot numbers.

The information regarding the effects of the sun on long wave daylight transmission and ultra short wave night transmission averaged in periods of a few days, is somewhat discordant differing at different times and on different stations. These discrepancies may be due to the relative phase shifts in the transmission and sunspot curves already mentioned.

Very few observations have been published on long wave night transmission, on broadcasting day transmission, nor, so far as is known, have any been made on broadcasting night transmission extending over more than one year.

There is in general a rough resemblance observed in the reception curves of different long wave stations lying in different directions from Washington. This would seem to imply either that there are simultaneous changes in the electrical conditions in the upper atmosphere over very large areas or that the conditions in the immediate neighborhood of the receiving station form the chief controlling factor in signal strength. Occasionally, however, marked differences in reception from stations in different directions have been noted, a phenomenon which is much more common in the case of the broadcasting and ultra short waves at night.

While the sunspot numbers give a rough indication of the conditions governing transmission, it seems probable that they are only an imperfect index of the particular form of solar activity which apparently is the chief agent in controlling radio phenomena.

* * *

Relations entre les parasites atmosphériques et les phénomènes météorologiques,

par Robert BUREAU.

L'étude directe des atmosphériques m'a conduit à répartir la plupart d'entre eux en trois catégories différenciées par les caractères de leur variation diurne.

On distingue ainsi : des *atmosphériques nocturnes* qui naissent vers le coucher du soleil et meurent à son lever — des *atmosphériques irréguliers* que l'on voit apparaître ou disparaître à toute heure du jour ou de la nuit — des *atmosphériques d'après-midi* qui surgissent brutalement vers midi et qui faiblissent vers 21 heures (fig. 1).

Par ailleurs j'ai été amené à rattacher les atmosphériques à trois types de situations météorologiques qui correspondent aux trois genres de variation diurne ci-dessus indiqués. Nous verrons ci-après que les atmosphériques nocturnes sont particulièrement nets dans les *situations anticycloniques*, que les atmosphériques irréguliers se rattachent aux courants de *perturbations du front polaire*, et que les atmosphériques d'après-midi naissent dans certaines *perturbations orageuses* indépendantes du front polaire.

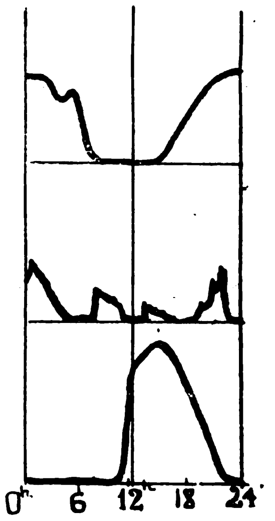

Fig. 1.
Représentation schématique des variations diurnes des trois catégories d'atmosphériques.

Comme l'étude des caractères météorologiques des atmosphériques nous conduit ainsi

à la même classification que l'étude de leur variation diurne, il y a tout lieu de supposer que les caractères de la variation diurne ne sont qu'une conséquence des causes météorologiques différentes qui provoquent l'activité plus ou moins grande des atmosphériques. Nous verrons qu'il en est bien ainsi; que, dans les trois cas, les atmosphériques sont d'autant plus violents que l'atmosphère est soumise à une agitation plus forte suivant la verticale, autrement dit que son instabilité thermique suivant la verticale est plus grande. Cette instabilité thermique peut elle-même avoir diverses causes et les principales sont :

a) La *turbulence* sous les surfaces d'inversion de température (et en particulier sous les surfaces d'inversion anticycloniques);

b) *L'instabilité verticale* due à l'arrivée de masses d'air polaire en des régions relativement chaudes ou due au passage de certaines surfaces de discontinuité;

c) Les violents *mouvements verticaux de convection* dus à l'échauffement solaire violent des couches basses par l'intermédiaire du sol.

1. — Les facteurs météorologiques.

Il importe de noter que si l'on a pu établir d'une manière précise les relations étroites qui rattachent les parasites atmosphériques aux phénomènes de l'atmosphère, c'est que les progrès récents de la météorologie nous ont fait connaître ces phénomènes et leur mécanisme avec une grande précision. Nous savons en particulier qu'il ne faut plus considérer la perturbation météorologique classique, c'est-à-dire la dépression barométrique, comme un individu météorologique formant un tout homogène, mais que, tout au contraire les dépressions barométriques sont des régions où se heurtent des masses d'air d'origine, de nature, et de caractères physiques différents; que l'identification de ces masses d'air est devenue l'un des buts principaux de l'analyse météorologique; et que leurs surfaces de séparation provoquent au sol et en altitude des surfaces de discontinuité dont le rôle est capital dans la formation des principaux phénomènes atmosphériques. La pression barométrique, considérée autrefois comme l'élément météorologique principal, n'est plus qu'un élément à considérer parmi beaucoup d'autres, et la forme des figures isobariques n'est souvent plus qu'une indication secondaire.

Alors que la simple comparaison des parasites atmosphériques aux diverses figures isobariques, et, en particulier, aux diverses formes de dépressions, ne saurait nous amener à énoncer des relations bien précises, puisque l'un des éléments de comparaison, l'élément météorologique, n'est ainsi que très vaguement déterminé, la comparaison des atmosphériques avec les caractères spécifiques des masses d'air d'origine et de nature bien définies, leur comparaison aussi avec les mécanismes divers des diverses surfaces de discontinuité nous révéleront des relations très étroites entre les phénomènes radioélectriques et les phénomènes météorologiques.

Il importe donc, au seuil d'une telle étude, de rappeler les principaux concepts de météorologie moderne auxquels, nécessairement, il sera fait appel par la suite.

Les *perturbations météorologiques* se groupent en *courants* dont les *lits* contournent de vastes régions où la pression se modifie peu pendant d'assez longues périodes et que l'on nomme, après Teisserenc de Bort, *centres d'action* de l'atmosphère. Il y a des *centres d'action positifs*, où la pression est relativement élevée, ce sont les *anticyclones*. Il y a des *centres d'action négatifs* où la pression est inférieure à la moyenne, ce sont les vastes zones dépressionnaires.

Parmi les courants de perturbations qui contournent les anticyclones, qui contournent ou traversent les zones dépressionnaires, il faut de suite donner une importance particulière à ceux qui se rattachent à un ensemble que Bjerknes a nommé le *front polaire*. Le front polaire se déroule tout autour de la terre le long des latitudes moyennes. Il est le lieu de rencontre des masses d'air dites *polaires* provenant des régions polaires, et des masses d'air dites *tropicales* venant plus ou moins directement des tropiques. Bjerknes a montré que les surfaces de contact entre ces deux masses d'air peuvent être mises en évidence sur des cartes météorologiques suffisamment précises par des discontinuités de la direction et de la vitesse du vent, de la température, etc., d'où leur nom de *surfaces de discontinuité*, que les sondages aérologiques révèlent l'existence de ces discontinuités en altitude où elles sont presque toujours beaucoup plus nettes qu'au sol. On constate ainsi que la pente de ces surfaces est très faible (quelques centimètres) et que l'air froid plus lourd est toujours au-dessous (voir fig. 7, partie supérieure). Les surfaces de discontinuité se déplacent. Ce déplacement peut s'opérer de deux manières, suivant que c'est l'air chaud qui remplace l'air froid ou l'air froid qui remplace l'air chaud. Dans le premier cas, l'air chaud monte au-dessus de la surface, se refroidit par détente et provoque ainsi de longues pluies continues. C'est ce qu'on nomme un *front chaud*. Dans le second cas, l'air froid expulse l'air chaud en se glissant en coin sous la surface de discontinuité. C'est le phénomène du *front froid* accompagné le plus souvent d'averses, de grains et même d'orages.

Un *cyclone* du front polaire se développe le long de la surface de discontinuité dans les conditions suivantes : une langue d'air chaud pénètre dans la masse d'air polaire; un front chaud se développe ainsi et progresse. Cependant, derrière la langue d'air chaud, l'air polaire progresse à son tour, refoule en la soulevant la masse d'air chaud. La surface de séparation de ces deux dernières masses d'air porte le nom de front froid. Le front froid s'avance assez vite pour que sa trace sur le sol vienne rejoindre la trace du front chaud, *coupant* ainsi au sol la langue d'air chaud de la masse d'où elle émane (phénomène de la *séclusion*). Après la séclusion l'air froid continue à se glisser sous l'air chaud qui bientôt ne touche plus du tout le sol (phénomène de l'*occlusion*).

Plusieurs cyclones naissent ainsi successivement l'un derrière l'autre le long de la surface de discontinuité, formant des *familles*. Puis la masse d'air polaire qui vient fermer l'un des cyclones est assez abondante pour rompre le front polaire et venir inonder d'immenses surfaces de pays parfois jusque dans les latitudes tropicales. Ce sont les *invasions polaires*, phénomènes qui mettent fin à une famille de cyclones. Le front polaire est ainsi discontinu autour du globe.

Les masses d'air que séparent les surfaces de discontinuité ne sont pas toutes des masses d'air ascendantes, se soulevant ou soulevées le long de ces surfaces. Dans de nombreux cas, elles fuient au contraire au-devant de la surface ou encore la surface fuit sous elles. Alors les masses d'air s'étalent et s'affaissent, se réchauffant adiabatiquement en provoquant la résorption par évaporation des nuages et des brouillards. C'est ce qu'on nomme les surfaces *d'affaissement* ou de *subsidience* (Abgleitfläche signalées par Stüve). On les rencontre dans un très grand nombre de situations, en particulier en avant des fronts chauds, derrière les fronts froids, sur la face occidentale des anticyclones, etc.

Dans les invasions polaires, les masses d'air polaire ne sont pour ainsi dire jamais homogènes, mais se refroidissent par échelons; et l'on y rencontre très souvent, se suivant les uns les autres, plusieurs *fronts froids secondaires* dont la structure rappelle beaucoup celle des fronts froids proprement dits.

Scherechewsky et Wehrlé ont montré que les surfaces de discontinuité du front polaire ne sont pas les seules qui provoquent la naissance de perturbations. Partout où deux masses d'air différentes se trouvent en présence, se développent de *pseudo fronts polaires* et s'établissent des courants de perturbations météorologiques qui rappellent ceux du front polaire. L'un des courants de ce genre qui intéresse le plus directement l'Europe occidentale est celui qui naît sur la face sud-est de l'anticyclone des Açores entre les masses d'air échauffées par le Sahara et les masses d'air relativement froides de l'Atlantique. La France est souvent traversée par ce courant de perturbations qui l'aborde par le sud-ouest. En général alors, le gradient barométrique est très faible et c'est là la situation orageuse typique.

2. — Répartition générale des atmosphériques dans les centres d'action et les courants de perturbations.

A. *Centres d'action anticycloniques.* — A l'intérieur de vastes anticyclones, la gêne provoquée par les atmosphériques est faible en général. Les atmosphériques ne sont cependant pas toujours absents dans ces cas. Mais ils s'y manifestent d'une manière très régulière, apparaissent le soir, se maintenant pendant la nuit et disparaissant le matin. Ces atmosphériques nocturnes d'anticyclones paraissent d'autant plus nets que les ondes sont plus courtes et que la saison est plus froide. C'est ainsi que pendant trois hivers de suite, on a pu constater que les échanges de radiogrammes météorologiques sur ondes courtes entre la France et le *Jacques Cartier* (naviguant entre la France et le golfe du Mexique) ont été particulièrement brouillés à la fin des nuits au cours desquelles un anticyclone s'étendait sur la France. Il semble bien également qu'à ces époques les atmosphériques gênaient davantage les émissions sur ondes courtes que les émissions sur ondes longues.

B. *Courants de perturbations.* — Si les stations d'observation se trouvent placées dans le lit des courants de perturbations météorologiques le plus grand désordre semble régner dans la répartition des atmosphériques dans le temps et dans l'espace. Il serait entièrement inexact de dire que le fait de se trouver dans un courant de perturbations entraîne la présence d'atmosphériques nombreux et violents, il serait également inexact de dire que les courants de perturbations n'ont aucune action sur les atmosphériques. La vérité, c'est que les *diverses phases* d'une perturbation météorologique entraînent des états électriques entièrement différents les uns des autres, de même qu'elles se caractérisent par des états du ciel manifestant une très grande variété. Si l'on ne fait entrer en ligne de compte que les atmosphériques susceptibles de gêner fortement les réceptions radiotélégraphiques, on sera amené à considérer que certaines perturbations sont pauvres et que d'autres sont riches en atmosphériques.

Les cas de perturbations riches en parasites se partagent en deux groupes :

a) Dans le premier, les atmosphériques gênants apparaissent aussi bien le matin que l'après-midi ou que la nuit et ils ne s'établissent que *successivement* dans les différentes stations d'un même pays pour disparaître de même *successivement* dans ces stations. Ces périodes de brouillage coïncident toutes avec les phénomènes météorologiques connus sous le nom *d'invasions polaires*. Je rappelle qu'on observe ces phénomènes à la fin du passage d'une famille de cyclones. Une immense masse d'air polaire se précipitant à l'arrière du dernier des cyclones de la famille vient déchirer le front polaire, se répand vers le Sud, atteint quelquefois les tropiques, et déverse dans les contrées de latitude moyenne une masse d'air relativement froide parce qu'elle provient en ligne presque directe des régions polaires. Cette masse d'air est surtout froide en altitude puisqu'elle n'y a rencontré aucune cause de réchauffement rapide; par contre elle s'est réchauffée sensiblement au contact de la mer et au contact du sol dans les latitudes moins septentrionales que celles d'où elle provient. Alourdie en haut, allégée en bas, cette masse d'air devient instable; elle est par suite le siège de courants verticaux accusés. Nous avons déjà dit que ces courants étaient éminemment favorables à la formation d'atmosphériques forts;

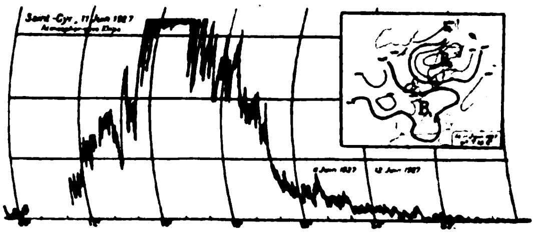

Fig. 2. — Variation diurne caractéristique des atmosphériques stagnants.

(Ces atmosphériques sont dus à l'action d'un pseudo front polaire venant du Sud-Ouest et auquel est dû en partie l'aspect de la carte isobarique et la dépression *B*.)

b) Le second groupe d'atmosphériques violents présente un tout autre caractère. Les atmosphériques sont partout localisés à certaines heures de la journée, ils débutent vers 11 h. 30 du temps local, ont leur maximum vers 15 heures et se prolongent jusque vers 21 heures et quelquefois plus avant dans la nuit. Mais, entre le lever du soleil et 11 h. 30 il règne un calme relatif, et très souvent on ne relate aucun brouillage dans cette période de la journée. Cette sorte de pulsation diurne s'observe simultanément dans tous les postes de la région soumise aux brouillages. Les atmosphériques y présentent simultanément une recrudescence vers midi et des affaiblissements à 21 heures (fig. 2). Ils peuvent être alors d'une rare violence et d'une continuité absolue; il arrive souvent qu'ils se prolongent comme un roulement ininterrompu pendant l'après-midi tout entière, rendant impossibles la plupart des réceptions et ne permettant que celles des émetteurs voisins ou puissants. Ce genre de brouillages, contrairement au précédent, n'intervient pas en toutes saisons. Il peut se constater en France à partir du mois d'avril, il semble particulièrement fréquent au mois de mai. Il ne semble pas qu'on l'observe entre le mois d'octobre et le mois d'avril. La répartition de ce genre d'atmosphériques à des heures fixes de la journée et le fait qu'ils apparaissent partout en même temps dans la région qui est affectée par eux, sans présenter de translation en surface, m'ont amené à les dénommer *atmosphériques stagnants* par opposition aux autres atmosphériques, dus, soit aux invasions polaires, soit aux fronts froids. J'ai donné à ces derniers atmosphériques le nom d'*atmosphériques migrateurs.*

En France, les situations météorologiques qui provoquent les *atmosphériques stagnants* sont celles au cours desquelles le pays est sous l'action de courants de perturbations orageux nés sur la face sud-est de l'anticyclone des Açores (voir fig. 2). Ces courants sont dus vraisemblablement au contraste de température entre l'anticyclone des Açores froid en altitude et les masses d'air africaines échauffées par le désert. Si, par un processus ou par un autre, l'anticyclone des Açores étend vers l'Est un prolongement sur la France, aussitôt le courant de perturbations météorologiques cesse de traverser le pays et aussitôt aussi disparaissent les atmosphériques stagnants. Tout se passe comme si l'anticyclone des Açores avait poussé un verrou barrant à la fois le chemin aux perturbations météorologiques et aux atmosphériques stagnants.

3. — L'action des perturbations météorologiques du front polaire.
Disparitions et recrudescences d'atmosphériques.

A. *Disparitions.* — Dans les latitudes moyennes l'arrivée d'un front chaud entraîne l'affaiblissement rapide des atmosphériques, quelquefois en moins d'une demi-heure. Ce phénomène est très sensible dans le cas d'un front chaud jeune, cas assez rare en France. Il l'est également dans le cas de fronts chauds en altitude, qui sont presque les seuls qu'on observe en Europe occidentale (cyclones occlus). Les noyaux de baisse barométrique, qui sont l'indice du passage d'une masse d'air chaud, au sol ou en altitude, s'accompagnent très souvent de la diminution ou de la mort des atmosphériques (fig. 3).

Ce phénomène d'affaiblissement et même de disparition est extrêmement général. Sous les latitudes moyennes, on l'observe aussi bien en été qu'en hiver, sur les continents que sur les océans (le *Jacques Cartier* l'a observé à chacune de ses traversées de l'Atlantique Nord), la nuit que le jour.

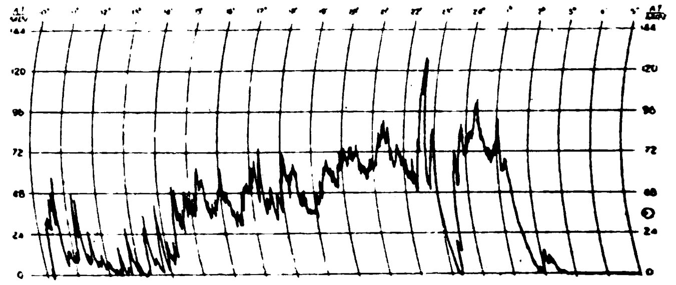

FIG. 3. — Diagramme d'atmosphériques du 21 octobre 1926. (Saint-Cyr.)

(Exemple de disposition due à l'arrivée d'un front chaud en altitude.)

Non seulement l'arrivée d'un front chaud au sol ou en altitude est accompagné d'un affaiblissement de l'activité des atmosphériques migrateurs, mais elle a également un effet d'affaiblissement marqué sur les autres catégories d'atmosphériques et en particulier sur les atmosphériques nocturnes. Quand un front chaud commence à aborder un pays, les atmosphériques nocturnes peuvent disparaître presque complètement et même parfois totalement. Il en résulte que l'absence d'atmosphériques la nuit, qui est un fait anormal, est un très sérieux indice de l'arrivée prochaine du mauvais temps, surtout lorsqu'on était auparavant dans une période anticyclonique. Cette action des fronts chauds sur les atmosphériques nocturnes d'anticyclone a des conséquences importantes : elle prouve que les deux catégories d'atmosphériques, atmosphériques nocturnes et atmosphériques migrateurs en liaison avec le front polaire, bien que distinctes l'une de l'autre ne sont cependant nullement des phénomènes indépendants qui se superposeraient. Sinon l'action du front polaire pourrait ajouter quelque chose aux atmosphériques nocturnes, mais non point y faire des retranchements. D'autre part, cette action des fronts chauds sur les atmosphériques nocturnes montre également que ces derniers ont fatalement une origine peu éloignée, sinon ils ne pourraient être affectés par des phénomènes météorologiques rapprochés. On ne peut en effet attribuer cette disparition anormale à des phénomènes de propagation lointaine d'ondes électromagnétiques, puisque l'arrivée d'un front chaud ne réduit pas la portée nocturne des postes émetteurs lointains.

La faible activité ou même l'absence d'atmosphériques s'observe non seulement à l'approche d'un front chaud, mais également dans les secteurs chauds quand ceux-ci viennent jusqu'au sol. Ce phénomène météorologique est assez rare en Europe occidentale il a pu être observé à plusieurs reprises sur l'océan Atlantique Nord à bord du *Jacques Cartier*. Même dans les cyclones de basses latitudes le secteur chaud n'est le siège d'aucune activité des atmosphériques.

L'air du secteur chaud se refroidit dans ses couches basses au fur et à mesure qu'il recouvre des latitudes plus élevées; il devient très stable puisqu'il s'alourdit en bas, en restant léger en haut, alors que le phénomène exactement inverse se passe dans l'air polaire. Ce processus qui engendre la stabilité de l'air dans les invasions d'air tropical (comme le processus inverse engendre l'instabilité dans les invasions polaires) est vraisemblablement aussi celui qui provoque un calme électromagnétique presque absolu dans les secteurs chauds et une grande agitation électromagnétique dans les invasions polaires.

Les cas d'une stratification horizontale stable des masses d'air ne s'observent pas seulement pour les secteurs chauds. On les remarque également dans les surfaces d'affaissement ou surfaces de subsidience.

Dans les surfaces de subsidience, l'air s'affaisse soit parce qu'il descend le long d'une surface de discontinuité, soit parce que la surface de discontinuité fuit au-devant de lui; dans ce cas comme dans l'autre la subsidience entraîne une stratification stable *et une disparition d'atmosphériques*. C'est à un phénomène de ce genre qu'il faut très probablement attribuer la mort des atmosphériques en avant d'un front chaud et non pas au front chaud lui-même. C'est également à un phénomène de ce genre qu'il faut attribuer la disparition provisoire des atmosphériques qui se produit, comme nous allons l'indiquer plus loin, aussitôt après le passage des lignes de grains.

Les disparitions d'atmosphériques à la suite de phénomènes météorologiques ne s'observent pas seulement dans les phénomènes rattachés au front polaire. On les constate aussi dans des phénomènes météorologiques des tropiques et en particulier dans les typhons, comme l'a signalé Gherzi. Les typhons se produisent dans des régions où les atmosphériques violents sont la règle absolue. Or quand un typhon s'approche d'un poste récepteur ou passe à proximité de lui, les atmosphériques s'affaiblissent très sensiblement et sont entièrement absents au centre du météore.

Pour en terminer avec cette question de la disparition des atmosphériques par suite de phénomènes météorologiques, je tiens à attirer l'attention sur une opinion assez répandue et qui est que les cyclones fabriquent des atmosphériques en leur centre et que, grâce au radiogoniomètre, on peut aussi déceler le centre de ces météores même à très grandes distances. Ce que nous venons de voir nous montre que c'est là une erreur. Tout au plus peut-on déterminer ainsi l'approche et la proximité de fronts froids bien marqués. Je vais maintenant étudier l'action électromagnétique de ces phénomènes météorologiques connus sous le nom de fronts froids.

B. *Apparition et renforcement des atmosphériques.* — Dans les latitudes moyennes, les fronts froids entraînent une augmentation ou une apparition des atmosphériques. Le phénomène est général, bien qu'il puisse se produire avec des intensités très diverses. Dans certains cas un front froid bien caractérisé produit une telle recrudescence d'atmosphériques que toutes les réceptions radiotélégraphiques en deviennent très pénibles. Dans d'autres cas au contraire les atmosphériques provoqués par le passage de la discontinuité météorologique sont trop faibles pour brouiller des émissions même peu puissantes, et on ne remarque le passage qu'à condition de le surveiller particulièrement. Même dans ces cas, l'influence du front froid sur le nombre et l'intensité des atmosphériques est indéniable.

Il faut rattacher l'action des fronts froids à celle des invasions polaires qui a été décrite plus haut. Les atmosphériques de fronts froids sont essentiellement des atmosphériques migrateurs qui se propagent en même temps que ces fronts. Le mécanisme de leur formation est identiquement le même que celui de la formation des atmosphériques d'invasion polaire. On peut même dire que les atmosphériques d'invasion polaire ne sont qu'un cas particulier des atmosphériques de front froid (fig. 4 et 5).

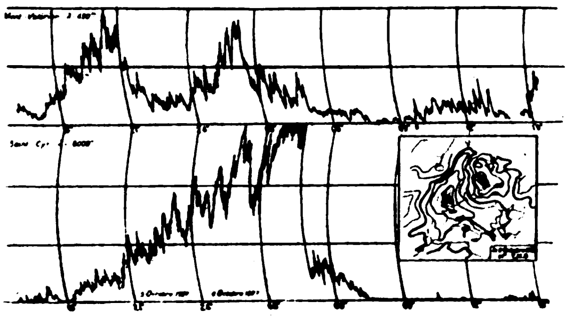

FIG. 4. — Enregistrements d'atmosphériques dus à l'air polaire.

On remarquera que, dans ce cas, l'évolution des atmosphériques peut être différente même dans deux localités peu éloignées (ici 20 km. de distance entre les deux récepteurs). Cependant la différence peut être due ici en partie aux longueurs d'onde (480 mètres d'un côté et 6,000 de l'autre.)

On constate, surtout en été, des discontinuités de front froid extrêmement accentuées qui apparaissent en général en France au sud-ouest du pays; la ligne de discontinuité s'étend sur plusieurs centaines de kilomètres de longueur et traverse peu à peu la France du Sud-Ouest au Nord-Est. Ces discontinuités sont accompagnées de parasites atmosphériques intenses, même lorsqu'elles ne donnent pas encore naissance à des orages, ni à des grains, ni à des précipitations, ni même à des formations nuageuses. Ceci montre bien que les atmosphériques de fronts froids ne sont pas une conséquence secondaire de ces fronts qui les provoqueraient par l'intermédiaire d'orages, de nuages ou de précipitations. Ils sont au contraire un phénomène primaire qui évolue parallèlement aux phénomènes météorologiques provoqués par le front froid et qui peut même se produire sans eux.

L'action des fronts froids du front polaire peut s'étendre très au Sud, jusque dans les régions tropicales, dans certaines conditions favorables. Certaines perturbations du front polaire peuvent se prolonger dans ces régions sous forme de fronts froids en altitude. On ne les met en évidence sur les cartes météorologiques que par certaines perturbations dans le régime des vents et leur passage se dénote souvent par des crochets brusques de la température et de l'humidité, par l'apparition de certains systèmes nuageux, quelquefois à peine indiqués et d'autres fois très vigoureux et donnant des météores violents. L'arrivée de ces fronts froids est annoncée plusieurs centaines de kilomètres à l'avance par une recrudescence très sérieuse des parasites atmosphériques qui, dans ce cas, sont, sous les basses latitudes, le seul élément météorologique susceptible de signaler localement et à l'avance l'existence d'une perturbation météorologique.

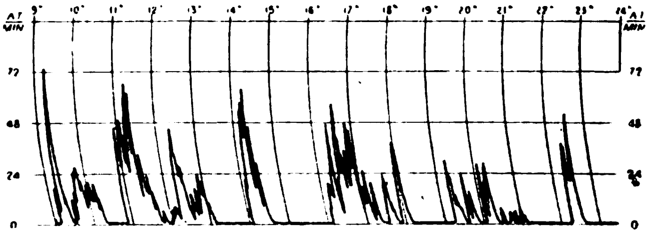

FIG. 5. — Diagramme d'atmosphériques du 15 novembre 1926, à Paris.

(Autre exemple d'atmosphériques dus à l'air polaire.)

Quelle est *la portée des atmosphériques de fronts froids?* L'expérience montre qu'elle peut être très variable (plusieurs centaines de kilomètres à quelques centaines de mètres).

D'après des observations faites à bord du

Jacques Cartier sur l'Atlantique il semble bien que ces différences de portée doivent être attribuées à la constitution physique des masses d'air; quand nous avons affaire au front froid d'un cyclone jeune et que les deux masses d'air voisines n'étant en présence que depuis peu de temps possèdent encore tous leur caractères propres, les atmosphériques n'apparaissent pas avant le front froid, mais aussi tôt que lui et quelquefois un peu après. Au contraire, quand la discontinuité de fronts froids est ancienne, la recrudescence des atmosphériques commence plusieurs centaines de kilomètres avant le passage du front.

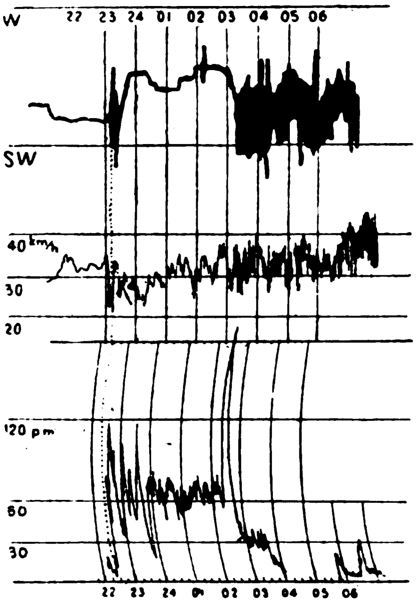

FIG. 6. — Exemple de simultanéité dans les variations de vent et les variations des atmosphériques (8 octobre 1926).

Courbe supérieure : Direction du vent au sommet de la Tour Eiffel.
Courbe intermédiaire : Vitesse du vent au sommet de la Tour Eiffel.
Courbe inférieure : Nombre par minute d'atmosphériques au Mont Valérien.

(L'augmentation brutale des atmosphériques à 22 heures, la pointe à 2 h. 30 coïncident avec le remplacement d'une masse d'air par une autre. Le décalage entre les heures au Mont Valérien et les heures à la Tour Eiffel correspond au temps mis par les surfaces de discontinuité pour aller d'un point à l'autre.)

En *Europe* la recrudescence des atmosphériques se produit à des distances qui varient entre 50 et 150 kilomètres avant le passage du front.

En *Afrique occidentale française* la recrudescence des atmosphériques se produit à des distances de 300 kilomètres pour des fronts froids *orageux.*

Les atmosphériques qui précèdent et annoncent le front froid ne sont probablement pas, tout au moins pour la plus grande part, comparables à une émission du front froid qui serait perceptible à distance. Ils ne prennent pas naissance dans le front froid lui-même, mais *dans l'air qui précède le front.* Ceci s'indique très nettement sur les enregistrements d'atmosphériques. On constate en effet que, loin de croître régulièrement jusqu'au passage du front froid comme cela se passerait s'ils en émanaient, les atmosphériques apparaissent brusquement à une certaine distance, puis présentent des variations très sensibles allant quelquefois jusqu'à s'annuler pour subir un violent renforcement au passage du front lui-même. D'autre part les enregistrements parallèles des phénomènes météorologiques et des parasites atmosphériques révèlent toujours dans le cas du temps de traîne ou du temps à grains une correspondance étonnante dans l'évolution des deux phénomènes (fig. 6).

Il ressort de tout ceci que la plupart de ces atmosphériques sont provoqués par le caractère purement local des masses d'air et que leur action s'atténue assez vite avec la distance pour qu'ils cessent d'être sensibles à quelques centaines de mètres du lieu de leur naissance, ce qui ne les empêche pas d'être parfois d'une rare violence et assez nombreux pour provoquer dans les réceptions les brouillages les plus graves.

Les fronts froids ne produisent pas seulement un renforcement des atmosphériques. Aussitôt après leur passage, on constate presque toujours une brusque diminution de ceux-ci et souvent même une disparition presque totale pouvant durer plus d'un quart d'heure. La bande de disparition d'atmosphériques qui fait suite à la bande de recrudescence et qui se promène à travers le pays en même temps que la ligne de grains, montre encore à quel point toute cette catégorie d'atmosphériques a un caractère nettement local (fig. 7).

Il est cependant certains fronts froids particulièrement intenses et accompagnés en général d'orages violents, dans lesquels on a constaté l'existence d'atmosphériques ayant une portée sensible dépassant certainement plusieurs centaines de kilomètres et quelquefois davantage. En Angleterre, M. Watson Watt s'est attaché à la recherche de tels atmosphériques. Il signale des cas où, à l'aide de procédés radiogoniométriques, il a pu mettre en évidence l'action des atmosphériques provoqués par des fronts froids situés à plusieurs milliers de kilomètres.

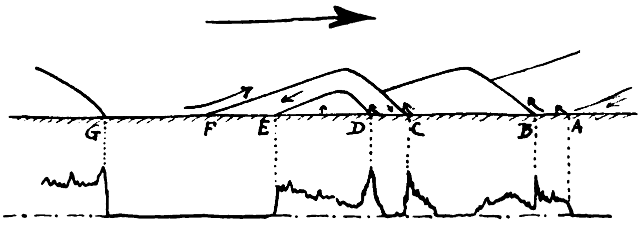

Fig. 7. — Schéma de l'évolution des atmosphériques dans le front polaire.

En haut, coupe verticale à travers les différentes masses d'air; en bas, atmosphériques.

En A, apparition des atmosphériques annonciateurs du front froid de trace B.

En C et D, maxima d'atmosphériques au passage de lignes de grains.

En E, disparition des atmosphériques en avant du pont chaud de trace F.

En G, apparition brutale d'atmosphériques coïncidant avec l'arrivée de l'air polaire succédant à l'air tropical du secteur chaud F G.

Chaque fois qu'on a cru mettre en évidence l'existence d'atmosphériques provenant du « Centre » d'une dépression on n'a constaté en fait que l'action classique des fronts froids.

4. — Les courants de convection et le gradient vertical de la température.

J'ai déjà signalé plus haut le contraste entre la *stabilité verticale de l'air tropical* des fronts chauds correspondant à une disparition d'atmosphériques et l'*instabilité verticale de l'air polaire* correspondant à une recrudescence de ceux-ci. Cette relation entre l'instabilité verticale de l'air et l'activité des atmosphériques est absolument générale et semble pouvoir expliquer la formation de toutes les catégories d'atmosphériques. A l'origine du caractère météorologique de chaque masse d'air, on trouve le mode de répartition verticale des températures dans cette masse. Suivant que la décroissance de la température avec l'altitude est plus ou moins rapide, l'air est plus ou moins instable verticalement. Toutes les propriétés météorologiques des masses d'air, et en particulier l'état du ciel, les nuages, les précipitations, dépendent directement du degré de stabilité ou d'instabilité verticale de l'air. De même *l'existence ou l'absence des parasites atmosphériques sont des conséquences de cette stabilité ou de cette instabilité verticale.*

L'instabilité des masses d'air peut avoir diverses causes auxquelles correspondent les diverses catégories d'atmosphériques. Quand l'instabilité est provoquée par le transport horizontal de masses d'air, c'est-à-dire à une origine dynamique (c'est le cas des perturbations au front polaire), nous nous trouvons en présence *d'atmosphériques migrateurs* (atmosphériques observés dans les invasions polaires et au passage des fronts froids). Le processus de cette instabilité a été décrit plus haut.

Dans certaines situations météorologiques en certaines saisons et sur les continents, l'échauffement des basses couches de l'atmosphère par l'intermédiaire d'un sol surchauffé par le soleil peut provoquer de violentes instabilités et des courants de convection intense. A cette instabilité correspondent les *atmosphériques stagnants* qui apparaissent vers midi et sont particulièrement violents vers 15 heures au moment où la convection est le plus accentuée.

La nuit, le refroidissement par rayonnement des basses couches de l'atmosphère provoque la formation d'une couche d'inversion, à la surface de séparation entre l'air plus chaud supérieur et l'air refroidi et lourd des basses couches. Le mouvement horizontal des masses d'air supérieur provoque dans la couche sous-jacente une instabilité tourbillonnaire à laquelle correspondent les atmosphériques nocturnes. L'existence de ces couches d'inversion est particulièrement sensible la nuit dans les anticyclones, par suite du rayonnement plus intense sous le ciel pur et par suite de l'absence des perturbations dynamiques capables de balayer l'instabilité. C'est pourquoi les atmosphériques nocturnes sont particulièrement nets dans les périodes anticycloniques, à tel point que j'avais été amené à les appeler *atmosphériques d'anticyclone.*

Comme l'instabilité verticale de l'atmosphère est un des éléments déterminants de l'aspect des phénomènes météorologiques et comme son observation directe à l'aide de sondages est onéreuse et parsemée, on voit toute l'utilité qu'on peut espérer tirer, au point de vue météorologique, de l'observation des atmosphériques, puisque cette observation fournira l'un des procédés les plus simples et les plus économiques pour obtenir des indications sur l'instabilité verticale de l'atmosphère.

5. — Évolution parallèle des atmosphériques et des individus météorologiques.

Nous sommes maintenant en état de comparer d'une façon logique l'évolution des parasites atmosphériques et l'évolution des individus météorologiques isolés. Nous verrons pourquoi, chaque fois que l'on veut commencer l'étude par cette comparaison brutale, on aboutit à des résultats contradictoires, soit à des conclusions inexactes :

a) *Les nuages.* — Les fronts chauds comme les fronts froids provoquent des formations nuageuses. Il est donc évident que certains temps couverts correspondront à une absence ou à une disparition d'atmosphériques et que d'autres correspondront à une recrudescence de ceux-ci. Une comparaison brutale de la nébulosité et des atmosphériques ne donnera donc aucun résultat. Par contre il y a une liaison très intéressante à établir entre les formes de nuages et les armosphériques. Comme les formes de nuages sont déterminées pour une très grande part par la structure verticale de l'atmosphère, les formes bourgeonnantes et tourmentées correspondent à une grande instabilité et en général à une assez grande activité des atmosphériques, les formes aplaties et stratifiées correspondent très souvent à l'absence ou à la faiblesse des atmosphériques. De même, les cas de ciel pur peuvent correspondre à l'absence ou à la présence d'atmosphériques.

b) *Brouillards.* — Dans l'ensemble l'activité des atmosphériques augmente quand la visibilité s'améliore, ceci par suite de l'influence des temps de traîne dans lesquels les mouvements de convection nettoient l'atmosphère de toutes poussières et provoquent en même temps des atmosphériques nombreux. Par contre il est certaines situations dans lesquelles des atmosphériques sont observés par brouillard et disparaissent en même temps que le brouillard. Il faut probablement rattacher ces situations au cas des atmosphériques d'anticyclone.

c) *Précipitations.* — On peut répéter à ce sujet ce qui a été dit pour les nuages.

d) *Tempêtes et cyclones.* — Une légende accuse les tempêtes et les cyclones d'être un nid d'atmosphériques. Aussi a-t-on cherché souvent à en déceler l'approche à l'aide d'un radiogoniomètre qui indiquerait à la fois la direction des atmosphériques et les centres de ces météores. Tout ce que nous venons de voir montre que, non seulement cette relation est inexacte, mais qu'elle n'a à proprement parler aucun sens, surtout pour les perturbations des régions tempérées (front polaire) dans lesquelles on distingue plusieurs phases complètement différentes. Chacune des phases joue un rôle particulier dans l'évolution des parasites atmosphériques; il suffit de se reporter à ce qui a été dit plus haut. Quant aux météores tropicaux, nous avons vu que le centre des typhons, loin d'être une usine d'atmosphériques, est l'endroit le plus calme qu'on puisse souhaiter pour assurer des réceptions radiotélégraphiques sans être gêné par eux. En ce qui concerne les cyclones des Antilles, je ne connais aucune observation précise d'atmosphériques faite en leurs centres, mais au contraire une observation de disparition d'atmosphériques faite à bord du *Jacques Cartier.*

e) *Grains et orages.* — Pour les grains, orageux ou non, il suffit de se reporter aux numéros précédents. Quant aux orages, une petite mise au point est nécessaire. Il est indéniable qu'un grand nombre d'éclairs sont accompagnés d'atmosphériques, mais il est non moins certain que ces atmosphériques ne forment qu'une infime partie de ceux qu'on observe même en période orageuse. Ceux-ci sont particulièrement intenses *avant* l'arrivée des orages, alors même qu'on n'observe aucun éclair; ils diminuent souvent pour disparaître parfois presque totalement *pendant* que l'orage éclate, et presque toujours ils sont très faibles ou inexistants *quand l'orage s'est éloigné* de la station d'observation. Les seuls que l'on observe alors sont

ceux qu'accompagnent les éclairs que l'on voit apparaître à l'horizon, c'est-à-dire qu'il en existe très peu et que les réceptions radiotélégraphiques même faibles ne sont nullement brouillées.

* * *

Measurements of the effective heights of the conducting layer and the disturbances of August 19, 1927 (¹)

by O. DAHL and L. A. GEBHARD,
Carnegie Institution of Washington
and Naval Research Laboratory (U. S. A.)

General Method. — The experiments described below were carried out during the summer of 1927. The method is that described by Breit and Tuve (2). As before, the signals were transmitted at the Naval Research Laboratory and received at the Department of Terrestrial Magnetism.

The experimental arrangements were almost identical with those employed by Breit and Tuve. The general scheme was as follows : A crystal-controlled, 4,015-kilocycle, 10-kilowatt set located at Bellevue was modulated so as to send out short interrupted trains of waves. The duration of each train was roughly 1/1,500 second, the space between the end of one train and the beginning of another being about 1/750 second. The signals were received on the roof of the main building of the Department of Terrestrial Magnetism. The receiving aerial was a small loop. This was connected to the first detector of a superheterodyne set having an intermediate frequency of 50 kilocycles. The second detector of the superheterodyne was fed into a resistance of 25,000 ohms connected between the filaments and grids of four 7.5-watt tubes (n° 210 x) used in parallel. The output of these tubes was passed through a General Electric oscillograph with a proper balancing arrangement for the steady plate-current. The resultant wave-form was photographed and observed visually.

The idea of the method is to photograph on the same record the trains arriving directly over the ground from Bellevue as well as their echoes arriving *via* the conducting layer. The lag between the arrival of the echo and the train which produced it gives the effective height of the layer.

Transmitter. — Figure 1 shows a diagram of the transmitter. A quartz crystal-oscillator was used as a master. Its output was first amplified by a 250-watt tube and then by a

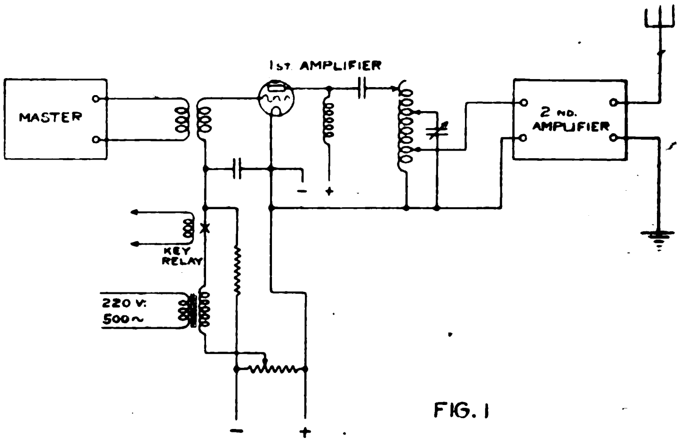

FIG. I

FIG. 1. — Diagram of transmitting circuit, crystal control, 10 kilowatts, 4,015 kilocycles.

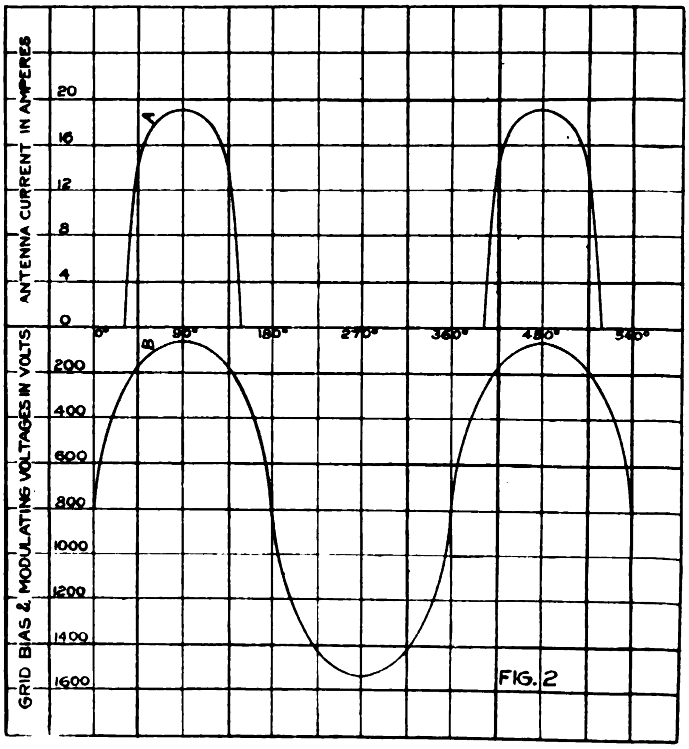

FIG. 2

FIG. 2. — Wave-form of transmitter as used in experiments.

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(1) Presented before the convention of the International Union of Scientific Radiotelegraphy, October 14, 1927.

(2) G. BREIT and M. A. TUVE (*Phys. Rev.*, vol. 28, 1926, pp. 554-575).

20-kilowatt tube. Control and modulation were accomplished in the first, i. e., the 250-watt stage of the amplifier. In controlling, with the key up, a high negative voltage was placed on the grid. This stopped the amplifying action of the 250-watt tube. The same principle was used in modulating.

The modulation voltage was obtained from a 500-cycle generator fed through a transformer. The 500-cycle output of the transformer was passed through a voltage divider, and a proper part of the grid biasing voltage was superposed on a constant negative bias. Figure 2 shows the actual relations. The constant negative voltage was 800 volts. The alternating 500-cycle voltage had an effective value of 525 volts. Its graph against time is shown on curve (*b*). The portions of time in which the 250-watt tube is operative are shown on (*a*). The humps shown on (*a*) represent approximately the envelope of the antenna current.

Figure 3 shows a photograph of the transmitting apparatus.

Receiving Apparatus. — The difference between the receiving apparatus used in these tests and in those of Breit and Tuve consists in the following items :

1) Different location of the apparatus. The measurements were made on the roof of the main building, while in the summer of 1925 they were made in the small Experiment Building.

2) The receiving aerial was a small loop 2 feet square instead of an antenna.

3) 7.5-watt tubes were used in the power amplifier instead of the 5-watt tubes used previously. Four tubes in parallel were used in each case.

4) A 7.5-watt oscillator loosely coupled to the superheterodyne was substituted for the 201 A oscillator used previously.

Results. — The results obtained are summarized in the following table.

Determination of Heaviside-Layer Heights

DATE	TIME	HEIGHT IN MILES	TRANSMITTER
1927	**h. m. h. m.**		
Aug. 15	2 00 — 2 15 p. m.	128 or 66	Antenna
16	10 00 — 10 15 a. m.	70 or 124	Antenna
16	2 00 — 2 15 p. m.	62	Antenna
17	10 00 — 10 15 a. m.	60 and perhaps 110	Antenna
17	2 00 — 2 15 p. m.	53	Antenna
19	. . . .	No reflection	Antenna
22	2 00 — 2 15 p. m.	112 or 80	Antenna
23	10 00 — 10 15 a. m.	103	Horizontal doublet
23	10 30 — 10 45 a. m.	104	Antenna
23	2 00 — 2 15 p. m.	104	Antenna
23	2 30 — 2 45 p. m.	124	Horizontal doublet
24	10 00 — 10 15 a. m.	92	Horizontal doublet (ground wave stronger than reflected)
25	10 15 — 10 30 a. m.	103	Horizontal doublet (reflected wave stronger than ground)

It must be noted also that not only did the reflected wave disappear on August 19 but also that the « ground » wave itself was received with difficulty. During the same period the reception of signals at the Naval Research Laboratory was decidedly below the average — some familiar stations not coming in at all.

Reports were received that the abnormal conditions caused a great deal of difficulty in copying on the San Francisco-Washington high-frequency circuit both day and night. For three days previous to and including the 21st much trouble was had in clearing traffic to London, it being the first time in over a month that London did not receive everything on the first transmission.

A report from London stated that during this period poor receiving conditions existed on all short-wave stations to the west of London, but that conditions were normal in receiving stations from other directions. Another London report stated that the same trouble was experienced with the Canadian Beam. The conditions, however, apparently did not affect the reception of Washington's 12,045 kilocycles frequency in San Francisco. On August 19, Lakehurst, New Jersey, was unable to receive Washington's 8 : 15 a. m. weather broadcast on 4,015 kilocycles, and Pensacola, Florida, could not copy this broadcast on 8,030 kilocycles. The failure of these two stations to get the broadcast was considered unusual, and could not be accounted for since the weather broadcast had been properly transmitted.

Several people reported to the Naval Research Laboratory that during the disturbance broadcast signals in the 500-1,500 kilocycles band also showed abnormalities.

We attempted to ascertain whether this unusual condition was definitely connected with a visible disturbance on the sun. No sufficiently definite information could be obtained because, even though there was an unusual spot in the southwestern quadrant of the sun, it had been active several days before August 19.

However, our information seems fairly definite to the extent of indicating that just before the disturbance the layer height was around 50 miles, while after the normal condition had been reached again the layer height was increased to 100 miles and more.

Figures 4 and 5 give reproductions of typical wave-forms observed during this period. The first of these was taken on August 25 and the second on October 8. Figure 6 is a reproduction of the photograph of the sun on August 19 kindly put at our disposal by S. B. Nicholson of the Mount Wilson Observatory.

* * *

International Comparison of Frequency Standards,

by J. H. DELLINGER,
Chief of Radio Section, Bureau of Standards,
Washington D. C. (U. S. A.)

This paper is a brief resume of the international comparisons of frequency standards in which the « Bureau of Standards » has participated in the past four years. The accuracy of such intercomparisons has steadily increased during this period, keeping pace with the increasing demands of practice. Those demands now require measurements of very great precision.

International comparisons of any physical quantity can be made by sending the standards of that quantity successively to the laboratories of the different nations. In the frequency comparisons that method has been followed with one exception. About four years ago it appeared that greater accuracy might possibly be obtained by another method, namely, the simultaneous measurement in the various laboratories of the frequencies of waves transmitted from stations of sufficient power to be received simultaneously in many nations. In 1924 such a set of comparisons was organized by the « Bureau of Standards » and measurements were made in the national laboratories of England, France, Italy, Germany and the United States. The results of such comparisons extending over a number of weeks were only fairly satisfactory. The accuracy of measurement was not as good as had been hoped. The result, briefly, was to show an agreement between the various countries within about two parts in 1,000. The methods used, and independent evidence of various kinds, were such that it was certain that the standards used in each of these countries were more accurate than this. The observed differences were therefore due in large part to the methods of measurement.

From the foregoing experience it was concluded that the more common method (actual transportation of standards from one laboratory to another) used in connection with other physical quantities should be considered anew. Just at that time, about three years ago, enough had been learned of the possibilities of piezo oscillators and piezo resonators to make it appear that they offered particular advantages as portable standards. Measurements upon piezoelectric devices therefore offered a method which might be superior to the scheme of measuring simultaneously the frequencies of transmitted waves. The first attempt of this kind was an informal series of measurements made in several national laboratories by Prof. W. G. Cady, Professor at Wesleyan University, Middletown, Connecticut. He took a number of piezo resonators (not oscillators) abroad; the results of his measurements are published in his article, « *An international comparison of radio wave length standards by means of piezoelectric resonators* » (1).

In December, 1925, the « Bureau of Standards » sent a piezo oscillator to Europe, sending it first to the « National Physical Laboratory » of England which was to send it in turn to General Ferrié in France, to Prof. Vallauri in Italy, to the « Physikalisch-Technische Reichsanstalt » in Germany, and then to be returned to the Bureau. A second piezo oscillator was sent in July, 1926, in the other direction, i. e., beginning with the « Physikalisch-Technische Reichsanstalt ». It is to be noted that complete piezo oscillators were sent, not merely the quartz plates.

The quartz plate is a standard of radio frequency having tremendous possibilities, but it is not a standard of absolute constancy as was assumed in unwarranted fashion by many people at the time that its possibilities in radio were first recognized. There are a number of factors which introduce variations in the frequency of the electromotive force produced by a vibrating quartz plate, and also in the frequency of response of a piezo resonator. These factors are the temperature, the particular method and details of the mounting of the quartz plate, the circuit constants of the associated circuits, and the methods of coupling between the circuit in which the quartz plate is inserted and the necessary auxiliary and measuring circuits. It is not true that highly accurate comparisons can be made by sending a quartz plate in the mail from one laboratory to another. The effects of the circuit constants may vary the frequency produced by a piezo oscillator several parts in 1,000, and therefore a complete piezo oscillator must be sent for accurate comparisons.

The measurements upon the two piezo oscillators sent to Europe by the « Bureau of Standards », on account of the necessary delays in getting from one laboratory to another, have only recently been completed. The results are very satisfactory, showing that the use of portable piezo oscillators is a far more dependable method of making international comparisons of frequency standards than simultaneous measurements of station frequencies. The differences between the measurements in the various laboratories have a maximum of eight parts in 10,000; the net result is to show an agreement by this method which may be summarized as a few parts in 10,000. It is uncertain as a result of this work as to whether the observed differences were due to variations in the piezo oscillators used as the means of comparison or to actual differences in the basic standards of the different countries.

The same method was used, namely the sending of piezo oscillators, to make comparisons between the frequency standards of the United States, Canada and Japan. In February, 1927, a piezo oscillator was sent to Canada, was there measured by the « Radio Service of the Department of Marine », then returned and measured again by the « Bureau of Standards ». The results were of the same order as those obtained in the European comparisons, and were considered by the Canadian administration as giving a comparison of standards to as great an accuracy as their measurements permitted.

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(1) *Proc. I. R. E.*, vol. 12, p. 805; December 1924.

The « Bureau of Standards » sent a piezo oscillator in March, 1927, to Japan. I have just received the results of the Japanese measurements from Prof. Yokoyama. The average of the Japanese values differs from the « Bureau of Standards » measurements by only one part in 10,000.

In February of this year a group of American commercial companies, the « General Electric C° », the « American Telephone and Telegraph C° », « Westinghouse C° », « Radio Corporation of America », « General Radio C° », and two departments of the government, the Navy and the « Department of Commerce », had a conference at the « Bureau of Standards », and drew up a program with a view to establishing a more accurate basis of frequency measurements. Each of these organizations had been conducting considerable research on this subject, and it seemed that progress could be made faster by combining the resources and experience of all the organizations. Incidental to the beginning of this program of work the « General Electric C° », « Westinghouse C° », and the Navy constructed a number of improved piezo oscillators. These are an advance over those previously used in that there is a thermostat provided to keep the temperature of the quartz plate constant.

As I was going to Europe this summer for the « Bureau of Standards » an opportunity was presented to use one of these instruments for comparisons with the national standards of the national laboratories of Europe. It was hoped that by taking this improved instrument to the European laboratories a frequency comparison could be obtained that would surpass previous ones in accuracy. I accordingly had the pleasure of making frequency measurements, all of which were very satisfactory, at the « National Physical Laboratory » in England, at the laboratory of the « Télégraphie militaire » under General Ferrié, in Paris, at the « Italian Navy Laboratory » in Livorno, Italy, and at the « Physikalisch-Technische Reichsanstalt », in Berlin. I wish to acknowledge the splendid cooperation given me in each of these laboratories by my collaborators, Dr D. W. Dye at the « National Physical Laboratory », Prof. R. Jouaust, in Paris, Prof. G. Vallauri, in Livorno, and Dr E. Giebe at the Reichsanstalt. The measurements were made in July and August.

We measured the frequencies of the piezo oscillator at the « Bureau of Standards » before I left the United States and again after my return. The instrument contained two quartz plates in a thermostatically controlled heated enclosure, the quartz plate being kept at a temperature of 46° C. Instruments were provided to insure that filament and plate voltages were always the same. The frequencies of both quartz plates were approximately 200 kilocycles.

It was interesting to find that in all the laboratories the same general method is used for frequency measurements of high precision. Typically, there are three generators placed in the laboratory about ten feet apart; one is the piezo oscillator under measurement, one is the auxiliary oscillator or heterodyne, and the third is the standard instrument against which the piezo oscillator is to be measured. There is coupled to each of these a single circuit which contains a receiving set with telephone receivers connected to it. The method of measurement is in all cases some variation of the simple procedure of listening for the frequency difference between the auxiliary generator and the piezo oscillator, and by one process or another reducing this difference to zero, and then adjusting to equality with the auxiliary generator the standard in terms of which the piezo oscillator is being measured (or else determining the difference between the standard and the auxiliary generator).

The results justified every hope. The differences between the different laboratories in these measurements ranged from zero to five parts in 100,000, the average of the departures from the mean being three parts in 100,000. This agreement is indeed as good as the degree of certainty of the national standards. It is con-

cluded that by using a portable temperature-controlled piezo oscillator in which the currents through the circuits are always adjusted to the same value, it was possible to get a 10-fold increase of accuracy over the use of simpler types of piezo oscillator as in the previous comparisons.

This is not by any means the limit of attainable accuracy. The instrument with which these comparisons were made was one upon which complete studies had not been made as to temperature equilibrium, frequency lag, and temperature coefficient of the quartz plate. No doubt as time goes on we can improve upon this and arrive at our goal, which has been set as an accuracy of one part in 100,000. On the whole, however, I feel that it has been demonstrated that the several national laboratories are measuring frequencies with an accuracy very satisfactorily in advance of the immediate requirements of radio practice. Those requirements are becoming increasingly rigorous, and the national laboratories must therefore continue their efforts for even higher accuracy of frequency measurement.

* * *

L'emploi de cellules photoélectriques, associées à des lampes à plusieurs électrodes, à la solution de divers problèmes concernant la mesure du temps.

par G. FERRIÉ et R. JOUAUST,
Tél. mil. (Paris, France).

La mesure des intervalles de temps présente un intérêt primordial dans un grand nombre de problèmes scientifiques concernant la radiotélégraphie, en particulier pour la détermination des fréquences, qui nécessite une très grande précision. De plus, l'emploi de la radiotélégraphie pour l'émission de signaux horaires, et l'utilisation de ces derniers pour les études relatives à la propagation des ondes, aux origines des perturbations atmosphériques (statics), etc., augmentent encore l'importance que présente la mesure du temps pour les spécialistes de la radiotélégraphie.

Il n'y a pas lieu d'entrer ici dans les détails des méthodes et appareils établis jusqu'à maintenant pour la détermination et la conservation de l'heure, ainsi que pour la mesure des intervalles de temps. Nous nous bornerons à indiquer quelques dispositifs que nous avons créés en utilisant les cellules photoélectriques au potassium associées à des lampes à plusieurs électrodes et à des amplificateurs employés dans la technique courante de la radiotélégraphie (1).

Aménagement des pendules astronomiques. — Les pendules astronomiques, utilisées dans les observatoires pour conserver l'heure déterminée par les observations astronomiques, sont parvenues à un très haut degré de perfectionnement. Leur marche journalière est très régulière et très faible, et n'est généralement pas supérieure à un centième de seconde. On peut donc mesurer de longs intervalles de temps avec une très grande précision.

En revanche, quand on compare les durées des diverses secondes données par ces pendules, on s'aperçoit qu'elles diffèrent entre elles de quantités notables atteignant parfois le centième de seconde. Ces pendules ont donc une précision insuffisante quand on se sert de leur intermédiaire pour mesurer de courts intervalles de temps, d'une durée de quelques secondes par exemple. Les causes de ces irrégularités sont les suivantes :

Les pendules des observatoires, étant placées loin des lieux d'observation, souvent même dans des caves, ne sont pas sous les yeux des astronomes et, pour permettre d'utiliser leurs indications, on emploie le procédé ci-après :

La pendule porte un dispositif qui toutes les secondes (le plus souvent toutes les deux secondes) ferme un circuit électrique. La fermeture de ce circuit donne passage à un courant qui actionne la plume d'un chronographe ou produit un « top » dans un téléphone. Le dispositif de fermeture est constitué par un cliquet porté par le balancier et engrenant avec une roue dentée. On conçoit que quelques précautions qui aient été prises pour la taille des roues, leurs dents ne sont pas identiques.

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(1) Nous avons entrepris ces travaux dès 1922 et leurs résultats ont été successivement communiqués aux réunions des Unions internationales d'Astronomie et de Géodésie-Géophysique à Rome en 1922, Madrid 1924, Cambridge 1926, et publiés également dans des revues astronomiques et radiotélégraphiques ainsi que dans les Comptes rendus de l'Académie des Sciences.

La fermeture du circuit n'a donc pas lieu à l'instant précis où le balancier passe par sa position d'équilibre, et la quantité dont elle en diffère varie avec la dent qui engrène avec le cliquet. La première idée qui vient à l'esprit pour éliminer cette cause d'erreur consiste à chercher un procédé pour observer directement le balancier.

Le principe du dispositif de ce genre que nous avons établi dès 1923 pour l'Observatoire de Paris était le suivant :

Un miroir était fixé sur le balancier et, chaque fois que le balancier passait par la position d'équilibre, les rayons lumineux émanés d'une lampe électrique étaient réfléchis par le miroir et tombaient sur la partie sensible d'une cellule photoélectrique au potassium. Le courant photoélectrique, amplifié par des lampes à 3 électrodes, était susceptible d'actionner des appareils enregistreurs.

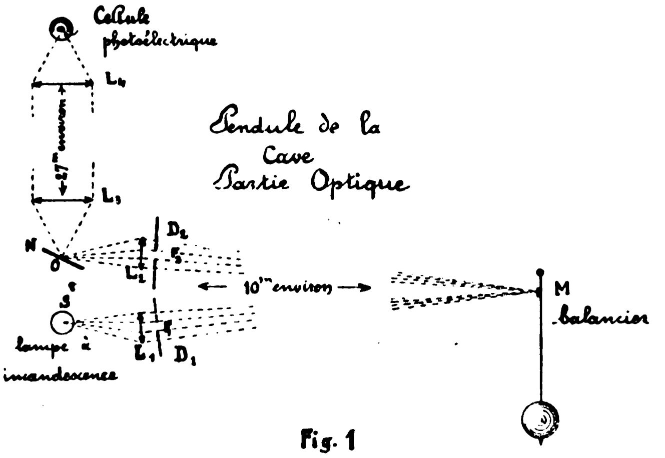

Fig. 1

Dans la réalité, le problème présentait des difficultés pratiques, car les pendules de l'Observatoire de Paris sont placées dans des caves à une profondeur d'environ 27 mètres. La figure 1 montre la solution adoptée.

Sur le balancier de la pendule était placé un miroir plan M. La lentille L_1 donnait sur ce miroir l'image d'une puissante lampe électrique S.

Dans un diaphragme D_1, placé devant la lentille, était ménagée une mince fente horizontale F_1. Ce sont les rayons émanés de cette fente qui venaient se réfléchir en M.

Le système était disposé de telle façon que lorsque le balancier était vertical, les rayons réfléchis par M pouvaient passer à travers une autre fente horizontale ménagée dans le diaphragme D_2. Ils étaient reçus par une lentille L_2 et donnaient au point O sur le miroir N une image de la lampe. Les rayons réfléchis par le miroir N, transformés en un faisceau parallèle par la lentille L_3, s'élevaient dans un puits vertical de 27 mètres de hauteur et étaient concentrés par la lentille L_4 sur la cellule photoélectrique.

On voit qu'à chaque passage du balancier par la verticale, la cellule était illuminée pendant un temps très court.

Le courant photoélectrique était amplifié par un amplificateur à deux étages, le premier comportant une lampe bigrille et le second un système de trois lampes ordinaires en parallèle (fig. 2).

Ce courant amplifié, de l'ordre de 4 à 5 milliampères, était susceptible d'actionner la plume d'un enregistreur, ou bien était envoyé dans le primaire du transformateur d'entrée d'un amplificateur à basse fréquence et donnait des « tops » perceptibles au téléphone.

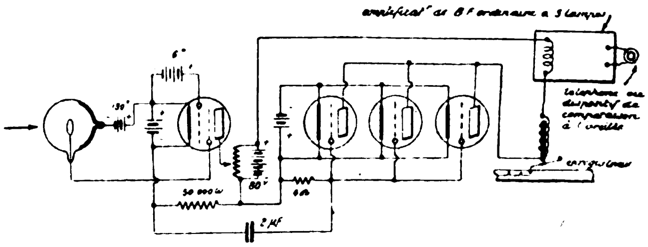
amplificat^r de B F ordinaire à 3 lampes
6v
130v
80v
50 000 ω
6 Ω
2 μF
téléphone ou dispositif de comparaison à l'oreille
enregistreur

Fig. 2. — Amplification pour la pendule de la cave de l'Observatoire de Paris.

Comme appareil enregistreur, on utilisait un des appareils à noir de fumée utilisés pour le repérage du son pendant la guerre; le système déviant étant un oscillographe à style Abraham du type dit électrométrique. La vitesse de déroulement du papier était de 6 centimètres par seconde.

Sur la même bande étaient inscrites les vibrations d'un diapason à 50 périodes entretenu électriquement sans contact par des lampes à 3 électrodes suivant le procédé indiqué simultanément en France par Henri ABRAHAM, en Angleterre par ECCLES et JORDAN.

Les bandes ainsi obtenues ont été examinées au moyen d'une machine à diviser et ont encore mis en évidence une inégalité des diverses secondes (on ne comparait bien entendu que les secondes de même signe). Ces irrégularités étaient moindres que celles relevées par la fermeture d'un circuit électrique par le balancier, mais elles étaient encore importantes (de l'ordre de 5 à 6 millièmes) et présentaient nettement une périodicité de l'ordre de la minute; ce qui indique bien que le mécanisme de la pendule devrait en être cause. Signalons que M. P. P. QUAYLÉ, du « Bureau of Standards », a également reconnu par la suite que les meilleurs chronomètres de cet établissement présentaient également, pour la durée de leurs diverses secondes, des irrégularités de plusieurs millièmes (1).

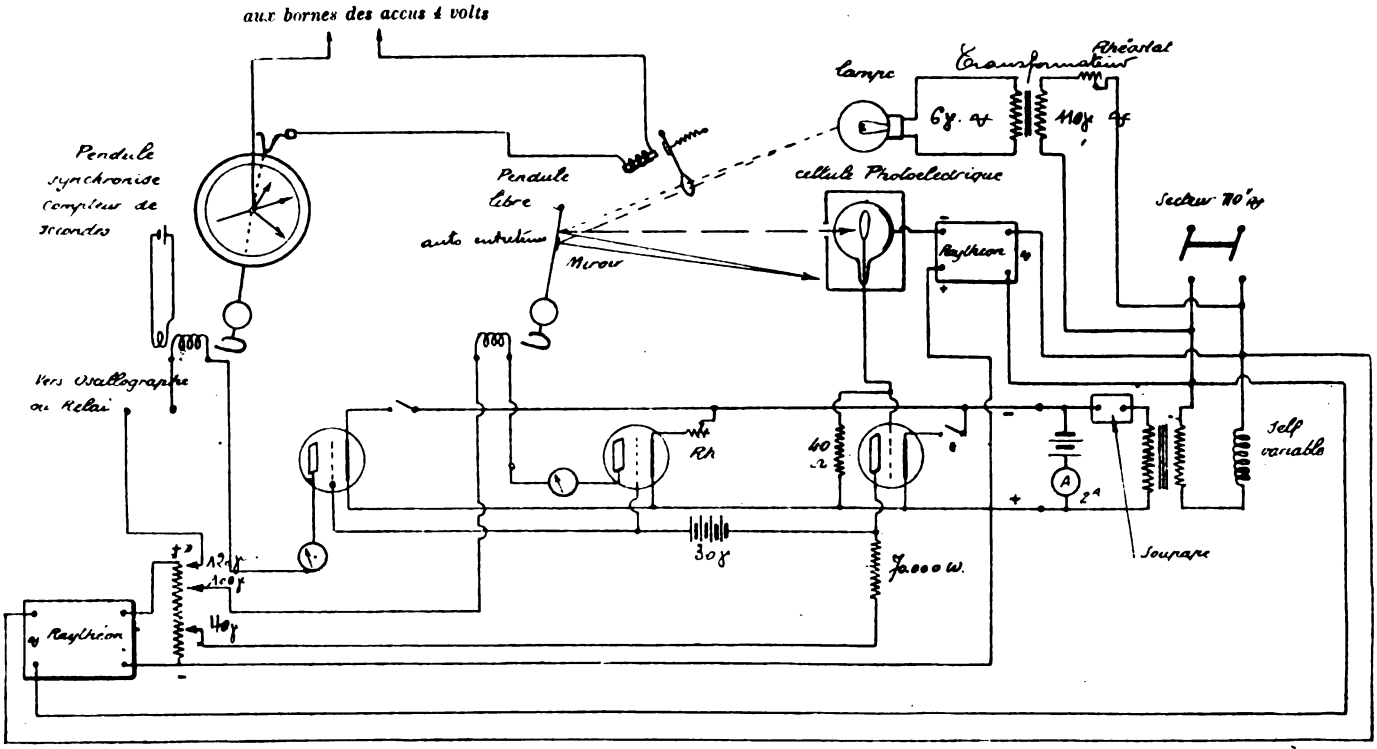

FIG. 4. — Pendule photoélectrique auto entretenu. (Installation faite à l'Observatoire de Paris.)

C'est évidemment dans le mécanisme de la pendule qu'il faut chercher la cause de ces irrégularités.

On sait que tout choc, qui n'est pas donné au balancier à l'instant précis où il passe par sa position d'équilibre, agit sur la période. C'est ce qui se produit avec les dents des rouages de la pendule qui, n'étant pas exactement taillées, n'agissent pas toutes au moment précis où le balancier passe par sa position d'équilibre. Il en résulte donc une variation pour la période du balancier.

Les considérations qui précèdent montrent que le balancier de la pendule est tantôt légèrement en avance, tantôt légèrement en retard sur le balancier idéal qui serait réalisé s'il n'existait aucune cause de perturbation et dont la période serait parfaitement régulière, la somme algébrique des écarts étant nulle au bout d'un temps de l'ordre de la minute.

Si donc on cherche à déterminer l'instant d'un signal ou d'un « top » enregistré sur la même bande que les battements de la pendule, en mesurant sur la bande l'intervalle de temps qui sépare ce signal ou « top » de la seconde la plus voisine, on commet une erreur égale à la différence de phase entre le balancier vrai et le balancier idéal au moment de la seconde servant de repère. Si, au contraire, on détermine le même instant en mesurant sur la bande les intervalles de temps qui séparent le signal ou « top » des 60 secondes les plus voisines, et en faisant la moyenne, l'erreur est éliminée.

Cette manière de procéder est longue, et de plus elle est difficile à appliquer quand il s'agit de comparer, non pas un signal ou « top » aux battements d'une pendule, mais une série de signaux radios dont l'enregistrement est parfois incomplet, ou une série de battements d'une autre pendule pour déterminer la différence de période des deux pendules et leur état relatif. La précision des mesures laisse donc à désirer en général.

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(1) *Journal of the Franklin Institute*, mars 1927, p. 407.

Les erreurs ainsi occasionnées se manifestent par exemple dans les publications du Bureau international de l'Heure relatives à l'opération mondiale de longitudes faite en octobre-novembre 1926. On note, en particulier, des écarts assez importants, pour les heures de réception des signaux radiotélégraphiques d'ANNAPOLIS, entre les divers relevés effectués sur une même bande. Ces écarts sont dûs au fait qu'on n'a pu utiliser pour chacun de ces relevés qu'un nombre restreint de signaux.

Pendule auto-entretenu. — Pour éliminer cette cause d'erreur, nous avons cherché à réaliser un pendule dont la période soit aussi constante que possible pendant toute la durée de l'enregistrement de ses battements qui est nécessaire pour effectuer les comparaisons désirées, c'est-à-dire pendant un temps relativement court, de l'ordre de 15 minutes au maximum.

Au lieu d'employer un pendule libre comme l'ont fait par la suite certains expérimentateurs, par exemple M. BROWN qui a utilisé un pendule géodésique (1), nous avons réalisé depuis 1925 un pendule entretenu sans aucune liaison mécanique par l'intermédiaire d'un rayon lumineux agissant sur une cellule photoélectrique au potassium. Le principe de l'appareil est le suivant :

Un balancier, du type de celui des pendulettes entretenues électriquement suivant le principe indiqué il y a longtemps par Cornu, porte un aimant plongeant horizontalement dans une bobine. Pour entretenir son mouvement, il suffit d'envoyer, chaque fois que le balancier passe par la position d'équilibre, un courant de sens convenable dans la bobine. Pour obtenir ce courant sans que le balancier ait à fermer aucun circuit par un contact matériel pouvant troubler sa période, sur la tige du balancier a été fixé un miroir qui est frappé par un rayon lumineux émané d'une lampe et, venant après réflexion, éclairer la cellule à l'instant convenable. Le courant qui est alors engendré dans celle-ci est envoyé dans un amplificateur à lampes puis dans la bobine. La durée de l'impulsion n'est que de 5 à 6 centièmes de seconde et se produit exactement à l'instant où le balancier passe par la verticale.

Une difficulté se présentait, le pendule (qui bat la demi-seconde) éclaire la cellule chaque fois qu'il passe par la position d'équilibre et par suite, le courant photoélectrique étant toujours de même sens, l'action sur l'aimant du balancier est de sens contraire pour deux demi-oscillations consécutives du pendule. La résultante est donc nulle. Le dispositif suivant a permis de tourner cette difficulté :

A côté du pendule libre est placée une pendulette de même période et de même type, mais munie de tous ses organes habituels (contacts, mouvement d'horlogerie, aiguilles, cadran), réglée au synchronisme aussi bien que possible, et s'entretenant électriquement elle-même par le procédé ordinaire. Toutefois, outre le bobinage servant à l'entretien, un autre enroulement concentrique au premier est parcouru par le courant amplifié d'origine photoélectrique qui sert déjà à l'entretien du pendule libre et qui assure alors un synchronisme parfait entre cette pendulette et le pendule libre.

Cette pendulette supplémentaire permet de compter sur son cadran les oscillations de son balancier et par suite celles du pendule libre qui est synchrone. En outre cette pendulette commande un dispositif qui, toutes les demi-secondes de même polarité (paire ou impaire), ferme un circuit commandant un obturateur mû électriquement et disposé sur le trajet du rayon réfléchi (1). Dans ces conditions, la cellule ne peut recevoir la lumière que toutes les deux demi-secondes et le pendule libre entretient automatiquement son mouvement sans difficultés.

Le dispositif complet est le suivant (fig. 3 et 4) :

Une lampe à filament rectiligne envoie sa lumière sur un miroir sphérique donnant de ce filament une image sur un diaphragme muni d'une fente placée devant la cellule. L'appareil est réglé de telle façon que l'image se forme exactement sur la fente quand le balancier est vertical. On obtient de cette façon des départs très brusques du courant photoélectrique.

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(1) *Bulletin of the National Research Council,* t. II, partie 12, n° 56, novembre 1926.

(1) En réalité, pour obtenir un bon fonctionnement de l'obturateur, on établit un léger décalage entre le pendule libre et la pendulette-compteur. On arrive à ce résultat en réglant la pendulette à une période très légèrement différente de celle du pendule auto-entretenu. Dans ces conditions on sait qu'une légère différence de phase s'établit entre le balancier synchronisateur et le balancier synchronisé.

En série avec l'anode de la cellule photoélectrique est placée une résistance de 40 mégohms connectée d'autre part entre le filament et la grille d'une lampe à 3 électrodes. Toute production de courant par la cellule provoque une chute de tension aux bornes de la résistance et par suite une variation du courant plaque de la première lampe (1).

Cette variation de courant est amplifiée au moyen d'un amplificateur du type dit « à courant continu », comportant deux lampes en parallèle.

Dans le circuit plaque de l'une des lampes est placée la bobine d'entretien du pendule libre, dans le circuit plaque de l'autre sont intercalées les spires de synchronisation de la pendulette qui commande l'obturateur et sert de compteur de temps. On place en outre en série les bobines de l'appareil enregistreur ou les enroulements d'un relais commandant les appareils d'émission du poste de T. S. F.

Pour éviter les sujétions et les ennuis causés par l'usage et l'entretien des batteries de piles nécessaires à la création du potentiel accélérateur de la cellule et à l'alimentation des plaques des lampes triodes, on utilise le secteur éclairage à courant alternatif qui alimente l'Observatoire de Paris. La tension du secteur, élevée à une valeur convenable par un transformateur, est redressée au moyen d'un « raythéon », les ondulations du courant étant adoucies par un filtre. Un raythéon alimente la cellule, un autre les plaques des lampes.

Les filaments des lampes sont également alimentés par le secteur alternatif, dont le courant est redressé par une soupape au tantale, une batterie d'accumulateurs de 4 volts étant placée comme batterie tampon. Il ne reste comme batterie de piles que la batterie de liaison entre les deux étages de lampes, batterie qui ne débite pas et ne nécessite aucun entretien.

La lampe qui éclaire la cellule est également alimentée par le secteur alternatif.

La tension du secteur étant variable, l'intensité lumineuse de la lampe, ainsi que le potentiel accélérateur de la cellule, sont suceptibles de varier. Il en résulte une variation possible de l'impulsion et par suite de l'amplitude du balancier auto-entretenu.

Pour remédier à cet inconvénient, la lampe qui alimente la bobine d'entretien de ce pendule est très peu chauffée. Les variations de tension aux bornes de la grille conduisent dans ces conditions le courant plaque dans la région de saturation. Le chauffage du filament de la lampe amplificatrice a été choisi de telle sorte que des chutes même importantes de tension du secteur permettent encore au courant photoélectrique d'amener le courant plaque de la lampe dans la région de saturation (1).

L'amplitude du balancier est très faible, de l'ordre de 3°, de façon à réduire au minimum les variations de période dues aux variations d'amplitude.

Pour exécuter des mesures avec cet ensemble, nous avons employé le dispositif déjà mentionné plus haut et comportant un enregistrement avec oscillographe ABRAHAM sur un appareil à noir de fumée, un diapason étant enregistré en même temps.

Voici les résultats de quelques-unes de ces mesures :

L'ensemble ayant été mis en marche à 8 heures du matin, le premier enregistrement a été effectué à 9 heures du matin, le second à 16 heures.

10 tops consécutifs ont été relevés chaque fois.

Enregistrement de 9 heures. — Durée *moyenne* de la période du pendule en fonction de la période du diapason :

49,972 périodes par seconde.

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(1) Pour amplifier le courant photoélectrique qui est très faible, il convient en général d'utiliser une lampe bigrille qui fonctionne sous faible tension plaque. Ceci évite l'ionisation par choc des gaz restants et, par suite, la tendance à la décharge de la grille par les ions positifs. Dans le cas actuel, avec le fort éclairement réalisé, une lampe ordinaire à trois électrodes peut convenir et a été employée parce qu'elle présente l'avantage d'éviter la batterie de piles qui serait nécessaire pour polariser la grille intérieure d'une lampe bigrille.

(1) D'autre part la tension des grilles des lampes de l'amplificateur à courant continu est réglée de façon que leur courant plaque soit nul lorsque la cellule n'est pas éclairée.

Numéro des secondes.	Écart relatif de la période mesurée par rapport à la période moyenne exprimée en dix-millièmes de seconde.
1	−4
2	+8
3	−8
4	−3
5	+4
6	−1
7	+4
8	+1
9	−1
10	0

Enregistrement de 16 heures. — Durée *moyenne* de la période en fonction de la période du diapason :

49,98 périodes (la température avait légèrement varié).

Numéro des secondes.	Écart en dix-millièmes de seconde.
1	−2
2	+2
3	−6
4	+6
5	+8
6	−5
7	−3
8	−1
9	0
10	+1

Ces résultats montrent bien qu'on peut considérer le pendule auto-entretenu comme donnant des oscillations constantes de période constante à moins de 1 millième de seconde près. La précision est même peut-être plus grande, car avec le procédé d'enregistrement au noir de fumée, le millième est tout ce qu'on peut garantir, en raison de l'épaisseur du trait, du frottement du style, etc., malgré toutes les précautions prises dans le relevé des bandes, et il convient de ne *pas perdre de vue que les nombres exprimés en dix-millièmes que nous avons donnés ne sont là que parce qu'ils résultent des mesures effectuées mais n'ont en réalité aucune valeur réelle.*

La marche du pendule s'est montrée très régulière. On a enregistré simultanément les battements de la pendule directrice de l'Observatoire et du pendule auto-entretenu pendant deux minutes au commencement et à la fin d'un même quart d'heure. On pouvait ainsi déduire la durée de la période du pendule auto-entretenu en fonction de la période de la directrice en faisant porter les mesures sur 900 secondes.

Une première mesure donnait pour le pendule auto-entretenu une période trop courte de 7/100.000^e. Une deuxième mesure effectuée 3 heures après donnait la valeur de 8/100.000^e.

Toutefois il importe de remarquer que ces mesures ont été effectuées à des instants de la journée où les variations du secteur électrique d'alimentation étaient relativement faibles, ce qui n'a pas lieu la nuit et à la tombée du jour et à ce moment malgré les précautions prises on ne peut répondre d'obtenir la même régularité. Il ne semble donc pas qu'on puisse *à l'heure actuelle au moyen de l'appareil tel qu'il a été utilisé* avec l'alimentation avec le courant du secteur d'éclairage, constituer un garde-temps conservant avec certitude le 1/100^e de seconde après vingt-quatre heures de fonctionnement. Toutefois avec une alimentation électrique n'ayant que de faibles variations, ce résultat pourrait être largement atteint et même dépassé.

Il conviendra toujours en tous cas, lorsqu'on aura utilisé le pendule auto-entretenu, de le comparer aussi rapidement que possible à la pendule directrice pour déterminer sa période.

Le pendule auto-entretenu, dont la période a été très exactement déterminée, se prête particulièrement bien à la détermination de la fréquence des diapasons qui sont ensuite employés pour la mesure des fréquences, en faisant usage du multivibrateur Abraham ou d'autres dispositifs.

Emissions de signaux radiotélégraphiques horaires. — Pour comparer avec précision les signaux radiotélégraphiques horaires rythmés, appelés aussi signaux scientifiques, aux battements de la pendule astronomique locale, il est évidemment nécessaire que ces signaux soient émis avec une parfaite régularité, c'est-à-dire soient également espacés. Il n'en est malheureusement pas ainsi pour le moment car les pendules qui commandent ces signaux ont les irrégularités dues aux rouages et qui ont été signalées et discutées plus haut.

L'emploi du pendule auto-entretenu a permis, au cours d'essais faits à l'Observatoire de Paris, de faire disparaître ce défaut et d'obtenir une émission de signaux dont l'espacement est constant à moins d'un millième près. Il suffit pour cela d'intercaler dans le circuit plaque de la deuxième lampe du dispositif de la figure 4 les enroulements des relais BAUDOT qui, de l'Observatoire de Paris, commandent les postes radio-télégraphiques de la Tour EIFFEL, d'ISSY et de BORDEAUX LAFAYETTE, pour faire émettre par ceux-ci des signaux commandés par le pendule auto-entretenu. Toutefois certaines difficultés nouvelles se présentent alors : Tout d'abord le pendule auto-entretenu doit donner 61 battements par minute. De ce côté, il n'y a pas de difficultés, c'est une question de réglage du balancier.

Le premier des signaux doit en outre être émis, aussi exactement que possible, à une minute ronde. Il faut donc que le pendule auto-entretenu donnant 61 battements par seconde, soit maintenu exactement à l'heure de la pendule garde-temps moyen de l'Observatoire, ou plutôt que chaque groupe de 61 battements du pendule auto-entretenu commence à l'instant de la première seconde de chacune des minutes du garde-temps, pendant toute l'émission des signaux.

Voici comment on y arrive. Toute la journée, sauf au moment des battements, le pendule auto-entretenu est synchronisé par la pendule garde-temps moyen, en substituant à son courant d'entretien photoélectrique, le courant fourni par le garde-temps moyen. Toutefois ce courant ne doit être envoyé dans la bobine du pendule auto-entretenu qu'une fois par minute, à l'instant de la première seconde de chaque minute du garde-temps, puisque celui-ci donne 60 battements par minute de temps moyen tandis que le pendule auto-entretenu donne 61 battements pendant le même intervalle de temps.

Cinq minutes avant l'émission des signaux horaires, on supprime la synchronisation du pendule auto-entretenu par la pendule garde-temps moyen, et l'on met en route le dispositif d'entretien photoélectrique. Puis dans la seconde qui précède la minute, on ferme le circuit qui fait agir le courant photoélectrique sur les relais BAUDOT commandant les émissions radiotélégraphiques.

Dans ces conditions, on a pu constater que le premier signal horaire était émis moins de 1/10 de seconde après la minute ronde de temps moyen, ce qui est suffisant pour les besoins de la pratique. L'heure exacte de ce premier signal est d'ailleurs donnée par la suite par le *Bulletin du Bureau International de l'Heure* pour les observateurs qui ont besoin d'une plus grande précision.

On peut se demander si les divers relais intercalés entre l'Observatoire de Paris et les postes d'émission, n'occasionnant pas des irrégularités dans les émissions, par suite du retard qu'ils apportent, retard qui pourrait être variable. Pour le vérifier, nous avons enregistré pendant cinq minutes à l'Observatoire de Paris sur la même bande à la fois les courants photoélectriques du pendule auto-entretenu et les signaux radiotélégraphiques, et nous avons mesuré le retard entre les deux enregistrements, au début et à la fin de la série de signaux.

Les résultats obtenus sont les suivants :

Enregistrement du début :

Numéro du top.	Différence entre le retard moyen et le retard individuel en dix-millièmes de seconde.
1	+ 3
2	— 4
3	+ 4
4	— 4
5	+ 1

Enregistrement de la fin :

1	+ 6
2	+ 1
3	— 6
4	— 4
5	+ 3

D'autre part, les deux valeurs moyennes ne différaient que de 1/10.000 c'est-à-dire d'une quantité inférieure à la précision des mesures.

Ces résultats montrent donc que le dispositif envisagé permettra d'émettre des signaux dont l'espacement sera constant à moins d'un millième de seconde près. Ce dispositif sera mis prochainement en service à l'Observatoire de Paris.

Détermination de l'heure. — Nous ne mentionnerons que pour mémoire une autre application des cellules photoélectriques à l'astronomie de position, et par suite à la mesure du temps : la détermination des instants du passage des étoiles au méridien. Cette utilisation a fait l'objet d'une publication dans les *Proceedings of the Institution of Electrical Engineers*, t. XIII, n° 4, août 1925, p. 461.

Etude de la gravité. — Signalons également qu'il est aisé de créer un dispositif analogue à celui de la pendule de la cave de l'Observatoire de Paris (fig. 1 et 2), mais beaucoup simplifié, pour mesurer la période d'un pendule libre établi pour déterminer l'intensité de la pesanteur (fig. 5).

Nous devons mentionner que divers expérimentateurs ont également essayé d'utiliser des cellules photoélectriques combinées aux lampes à plusieurs électrodes pour des buts identiques à ceux que nous poursuivons depuis 1922 et que nous avons atteints depuis 1925.

QUAYLE, au « Bureau of Standards » pour l'étude des diapasons, a utilisé comme indicateur de temps un pendule libre portant un miroir réfléchissant un rayon lumineux venant actionner une cellule photoélectrique (1).

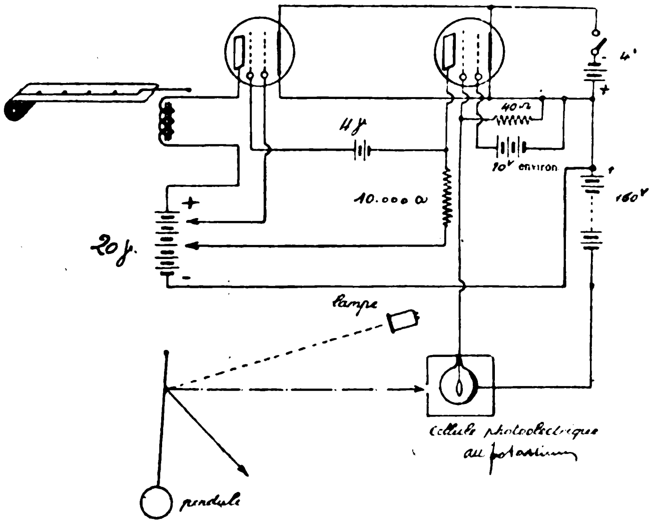

FIG. 5. — Dispositif d'enregistrement photo-électrique pour pendule géodésique.

De même GOULD, au « Bureau of Standards », aurait cherché récemment à commander l'émission de signaux horaires par un pendule libre actionnant une cellule sensible à la lumière.

Dans les laboratoires de la BELL C^{ie}, il aurait également été réalisé en 1926 un pendule auto-entretenu par l'action d'un rayon lumineux. Le mode opératoire était un peu différent de celui que nous avions indiqué. Le courant photoélectrique provoquait la fermeture d'un relais et celui-ci fermait sur la bobine excitatrice de la pendule le circuit d'une pile.

L'action photoélectrique remplaçait donc uniquement l'ensemble cliquet roue dentée utilisé habituellement.

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(1) *Journal of the Franklin Institute*, mars 1927, p. 407.

Precision Determination of Frequency,

by J. W. HORTON and W. A. MARRISON,
Bell Telephone Laboratories, New York (N. Y., U. S. A.)

When we speak of the frequency of a wave or, in fact, when we use the word frequency in any connection, we mean, in general, the number of times a periodic occurence takes place within a given interval of time. Consequently the frequency of a recurrent phenomenon is the reciprocal of the time interval required for the variation to pass through one cycle provided the duration of any given cycle is identical with that of any other, or, in other words, that the variation has a constant frequency. Since, therefore, frequency may be expressed completely in terms of time, it is neither necessary nor desirable to have any fundamental standard of frequency other than the accepted standard time interval.

The present standard of time is, of course, the sidereal day, which is the time required for the earth to make one complete revolution in space. A succession of sidereal days, therefore, constitutes a recurrent phenomenon the duration of any cycle of which is, by definition, equal in time to the duration of any other cycle. In other words, the variation has the essential characteristics required of a standard of frequency. The mean solar day, in terms of which all measurements of time are expressed, must be considered as a practical standard the determination of which is made in terms of the sidereal day.

There is a unique difference between a standard of time — or frequency — and standards of most other quantities. For example, the standard unit of mass or the standard unit of length may be given physical embodiments and may be put in a safe where their identity will be preserved over extended periods. Unlike a mass or a length, an interval of time cannot of itself be preserved nor can it readily be given a physical embodiment which by virtue of its great constancy may be used as a fundamental standard. At present, therefore, all precision measurements of time must be referred directly to the rate of the earth's rotation.

Having once concluded that the fundamental

standard of time is, *ex officio*, the fundamental standard of frequency, there remains simply the problem of comparing the rate of any periodic variation which is to be measured with the rate of the earth's rotation.

If there were available only the periodic phenomenon of unknown rate and the intervals defined by the earth's rotation, it would be necessary that the unknown phenomenon maintain its rate unchanged throughout an entire interval covered by one rotation of the earth. In this case the measurement would consist in counting the number of times the unknown variation repeated itself during the interval. Due, however, to the availability of means for accurately defining time intervals less than the sidereal day to the required precision, it is, of course, unnecessary to maintain the rate of the variation to be measured over the longer interval. When we recognize that any means used for evaluating the time of short intervals is itself executing periodic variations of equal duration, we realize that it is a secondary standard of frequency as well as a secondary standard of time. Thus the Riefler clocks at the National Bureau of Standards and at the United States Naval Observatory become our most practical working standards of frequency (1). In terms of the oscillations of their pendulums their frequency may be said to be unity when referred to the second.

A secondary standard such as a high grade seconds pendulum is unsuited to the actual determination of the frequency of such variations as are of interest in electrical communication, both because of the excessively high ratio between the rates of the occurrences to be compared and because, in its usual form, the motion of a clock pendulum is not well suited for comparison with electrical variations. It is desirable, therefore, as the first step in the precision measurement of the frequencies of electric waves, to provide a suitable reference standard. The requirements of such a standard are that its rate should be of the same order of magnitude as the rates to be measured, that the form of the variation which it controls should be suitable for convenient comparison with the variations to be measured, and, finally, that its rate shall be sufficiently constant so that the total number of variations which it executes in a time of such duration that it may be defined with high precision may be taken as the rate of the variation over shorter intervals of time. This last requirement again emphasizes the inherent similarity between secondary standards of frequency and secondary standards of time. For convenience, it should also be possible to adjust the rate of the frequency standard to some prescribed value within such limits that the error may be neglected in the majority of measurements.

Original equipment. — A secondary standard having the characteristics mentioned above was described several years ago by the authors of the present paper in collaboration with Mr. N. H. Ricker. This standard consists of a 100 cycle tuning fork maintained in vibration by an amplifier regeneratively connected through the fork by electromagnetic coupling. Means are provided for obtaining from the electrical portion of the resulting oscillating system a sinusoidal alternating current the frequency of which is constant to high precision. Standards of this general type are becoming extensively used, as will be seen by referring to the bibliography. A brief survey of the present status of this 100 cycle standard is of interest not only because of the improvement in its performance since the original report was presented, but also because the experience which has been gained from its use has been of value in the development of standards of still greater utility.

The fork which was described in the paper already referred to ran continuously from April, 1923 to May, 1927 except for four intervals totalling about three days. Of these interruptions two were from accidental causes and two for the purpose of making minor changes in the system. Throughout this entire period the temperature of the fork, as maintained by its thermostatically controlled water bath, was held at approximately the value for which its rate is 100 cycles. Since the temperature coefficient of frequency for the particular fork in question is 0.0109 per cent per degree Centigrade, it is necessary to keep the temperature to within 0.01° C of the prescribed value in order that the rate shall be correct to one part in a million. It has been found that the temperature coefficient, instead of being a detriment, has furnished an excellent means for adjusting the frequency, making possible small changes the amounts of which may be accurately predetermined. During the four years of operation, the change in the frequency of the entire system due to aging of the fork and to all other causes, as determined by the change in the temperature — indicated by a Beekman thermometer — at which the rate is exactly 100 cycles, has been less than 0.004 per cent.

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(1) This, of course, applies to the United States only; but a similar statement may be made of any national reference standard of time.

The synchronous motor described in the previous paper has been replaced by an improved form shown in Fig. 1. The original motor was coupled to the clock by means of a gear reduction driving a commutator, from which seconds impulses were supplied to a clock train having an electromagnetic stepping device. The present motor is geared directly to the clock train, thus completely avoiding errors due to the mechanism. In spite of the lack of confidence expressed by many people in the impulse type of synchronous motor, both of these mentioned have been found to give entirely satisfactory operation over long periods of time. In fact, the only occasions on which the motors have ever stopped in service have been those on which power was taken off some portion of the system.

During tests on this frequency standard, it was found that it constituted a far more reliable timekeeper than the electrically maintained pendulum clock which was used to obtain the data already published. The pendulum clock was, therefore, dispensed with and all measurements of the rate of the fork are now made by direct comparison with the mean solar day as defined by the radio time signals sent out from the United States Naval Observatory. By means of its second hand, which is concentric with the hour and minute hands and which rotates uniformly, the daily error in the fork controlled clock may be determined to 0.2 second, giving its average rate for the day to approximately three parts in one million. For greater accuracy there is provided, in the gear train between the motor and the clock, a shaft rotating once per second and operating a contact by means of a cam. Pulses from this contact may be recorded simultaneously with the radio time pulses on a moving paper tape by means of a two-element siphon recorder. From the record thus obtained, the error of the clock may be determined to 0.01 second, increasing the accuracy of the determination about 20 times.

The data shown by the chart of Fig. 2 are typical of the performance of this system. On this chart the error in the clock reading is plotted against days. The rate is obtained from the slope of the curve; when it is straight the rate is constant; when it is horizontal the rate is exactly 100 cycles. Attention is called not only to the constancy of the rate, which at no time during the period covered by this record departed more than 0.0007 per cent from the mean rate, but also to the precision with which the system was adjusted to the desired absolute value.

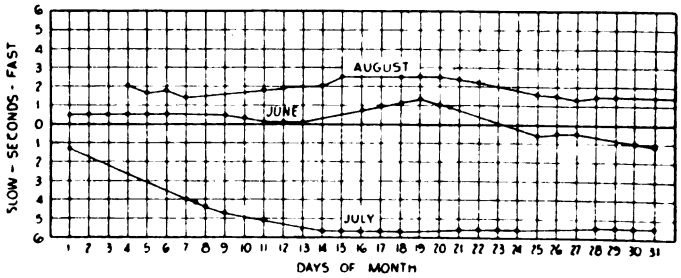

FIG. 2. — Daily Error in Clock Controlled by 100 Cycle Frequency Standard.

Mean Rate for Three Month Period :
99.99991 Cycles.
Average Deviation from Mean Rate :
0.00016 Cycles.
Maximum Deviation from Mean Rate :
0.00067 Cycles.

A method for the comparison of high frequencies with the 100 cycle standard is also outlined in the previous paper. This method involves the use of harmonic producers and of harmonic selecting networks. By repeated harmonic production and selection it is possible to obtain any multiple of the fundamental frequency to a limit determined by the care taken. Theoretically the process may be extended indefinitely, but practically there are difficulties in going beyond two or three stages. These difficulties arise from small irregularities in the frequency or in the amplitude of the current in the initial stages of the system, all of which result in frequency irregularities in the final wave. While these may be entirely negligible in the wave in which they originate, they are enormously magnified in subsequent stages. With ordinary care it is feasible to obtain from the 100 cycle standard current a current having a frequency of 100,000 cycles per second or even higher. By the use of a cathode ray oscillograph, an independent oscillator may be adjusted so that its frequency is an exact multiple of the frequency of the current thus obtained. This process may be repeated by successive stages up to the limit of the oscillograph tube.

The system, therefore, contains three essential elements : The regeneratively driven fork constitutes a source of alternating current, the frequency of which is 100 cycles to a very high precision. The synchronous motor and the gear train of the clock constitute a rate reducing mechanism having a ratio of approximately ten million to one. The harmonic producer system and the cathode ray oscillographs may be operated so as to increase the frequency in the ratio of several thousand to one. It is, therefore, practicable by means of this system to determine the frequency of an electric wave, using the mean solar day as a standard, when the ratio between them does not exceed about 10^{11}.

Present equipment. — At the time the development of the 100 cycle standard was undertaken, the frequency range over which measurements were required to high precision did not exceed several hundred thousand cycles per second. For this work the frequency chosen for the secondary standard was quite satisfactory. Since then, however, more and more attention has been given to the higher frequencies until it has become necessary to make measurements to a very high degree of accuracy up to several million cycles per second. Any appreciable increase in the frequency of the reference standard is obtained at the expense of an increase in the ratio between its rate and the mean solar day. This is not particularly objectionable, however, since the comparison between these two rates may be made with permanently adjusted apparatus designed expressly for this fixed ratio, whereas comparisons between unknown rates and the reference standard must be made by carefully adjusting apparatus capable of working over a wide range of ratios. More important still, it has been found that the frequency of a given current can be controlled by a current of higher frequency with much greater stability than by a current of lower frequency. Because of these various factors, therefore, there is need for a standard of the general type just described but having a fundamental frequency many times higher. Such a standard has been developed and some preliminary data as to its constancy of rate have been obtained.

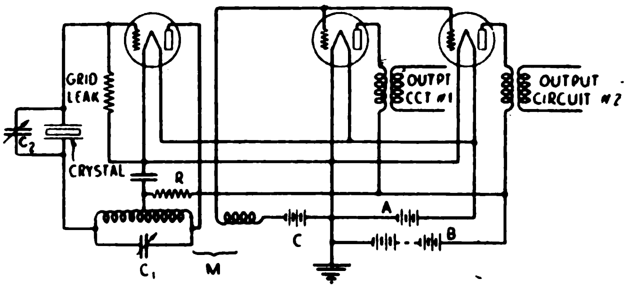

Fig. 3. — Circuit of Oscillator for High Frequency Standard.

The high frequency generator of this standard is a 50,000 cycle quartz crystal controlled oscillator having circuit elements and controls that give a high degree of stability. The circuit of this oscillator is shown in Fig. 3. It is of the Hartley type, differing from the usual form only in having a resonant piezo-electric crystal connected in the grid circuit. This type of circuit is used because it is convenient, by means of circuit adjustments, so to control the phase of the regenerative feedback that maximum stability is obtained. Being an efficient oscillating circuit it also permits of using the crystal loosely coupled to the electrical circuit, thus permitting full advantage to be taken of the very low decrement of the crystal.

The crystal is adjusted by lapping so that the frequency of the circuit controlled by it is 50,000 cycles exactly at a given operating temperature. Minute corrections that are subsequently required can be made by means of a small variable condenser in parallel with the crystal.

The crystal controlled oscillator is coupled to two output circuits through vacuum tubes, having their grids in parallel, loosely coupled to the tuning coil. In this way considerable output current at 50,000 cycles can be obtained with no possibility of reaction on the oscillator from external circuits.

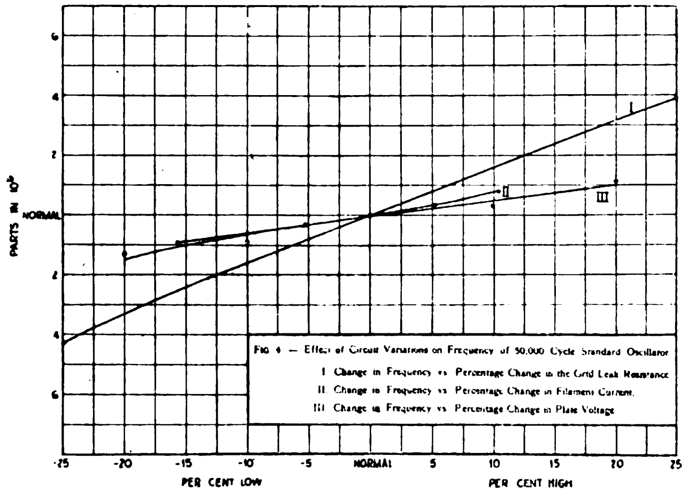

Fig. 4 — Effect of Circuit Variations on Frequency of 50,000 Cycle Standard Oscillator
I Change in Frequency vs Percentage Change in the Grid Leak Resistance
II Change in Frequency vs Percentage Change in Filament Current.
III Change in Frequency vs Percentage Change in Plate Voltage

The three curves in Fig. 4 show the frequency stability of the oscillator under variations in filament current, plate voltage, and grid leak resistance. The departure from normal frequency in parts in a million is plotted against departure in per cent from normal filament current, plate voltage, and resistance.

The variation with grid leak resistance is greatest, but due to the use of a special type of resistance that is expected not to vary as much as 0.1 per cent in service, the variations in frequency due to this source are negligible.

The variation with battery voltage is the most serious factor, being in the same sense for both batteries. These voltages are controlled at present to about ± 2 per cent, therefore variations in frequency of about three parts in ten million may be expected due to them. Of course, as has been done in other cases, it is possible to compensate the circuit for variations in voltage so that any tendency for a change in frequency in one direction is offset by an equal and opposite tendency.

The curves of Fig. 5 show the variations in frequency of the oscillator for changes in the condensers C_1 and C_2. These curves show variations in frequency in parts in a million and are plotted, in the case of condenser C_2, against dial settings, and in the case of condenser C_1, against the capacity in micro-microfarads. Due to the linearity of the adjustment obtained by condenser C_2 it is possible to make predetermined minute changes in the operating frequency. The proper adjustment for condenser C_2 is very nearly that value for which the change in frequency with capacity is zero. Under this condition the small changes in the electrical circuit due to temperature variations have an entirely negligible effect on the frequency.

The quartz crystal in its mounting is shown in Fig. 6. It vibrates in the direction of its length and is supported on a short piece of felt at the center in order to allow free vibration. It is held in place and separated from the plates by silk threads. The logarithmic decrement of this crystal in its mounting, the whole being measured as an electric circuit, is about 0.00012.

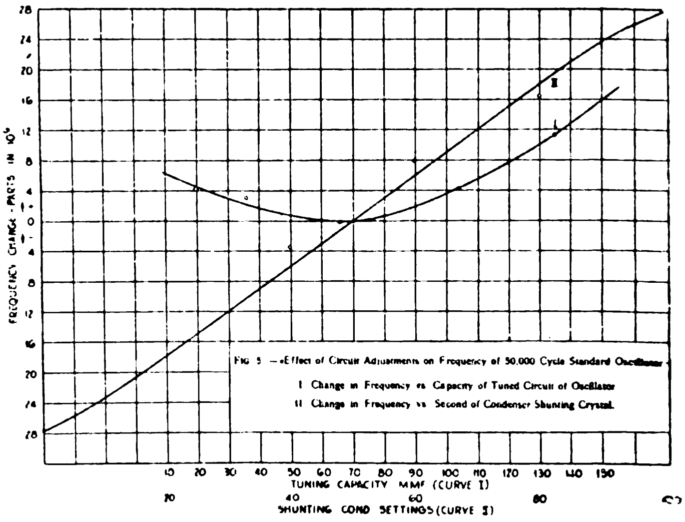

Fig. 5 — Effect of Circuit Adjustments on Frequency of 50,000 Cycle Standard Oscillator
I Change in Frequency vs Capacity of Tuned Circuit of Oscillator
II Change in Frequency vs Second of Condenser Shunting Crystal

The conductor plates are made very rigid in order to keep the separation constant, since a variation in this spacing as small as 0.01 mm would cause an appreciable error in frequency. The temperature coefficient of frequency is about 0.00038 per cent per degree Centigrade, requiring a control of temperature constant to within 0.025° C in order to keep variations due to temperature change alone within one part in ten million. Measurements on the effect of atmospheric pressure, covering the range from 760 mm to very low pressures, show the frequency to be approximately a linear function of the pressure. For the particular crystal measured, it was found that an increase in pressure of 140 mm caused a decrease in frequency of 0.001 per cent.

The thermostat used at present to control the temperature of the crystal is shown in Fig.7. It consists of a steel cylinder with hollow walls filled with mercury which expands when heated into a capillary tube, as in a thermometer. At a certain temperature contact is made on a pointed tungsten wire (not shown) which operates a mechanism for changing the rate of heating applied through a resistance coil wound on the outside of the steel cylinder. The crystal is mounted within the cylinder and the whole device is enclosed in a balsa-wood box for heat insulation. By means of this arrangement the temperature at a point within the cylinder may be kept at a prescribed value over long periods.

It is of interest to note that the temperature of the crystal when operating is not exactly that of the space surrounding it because some energy is dissipated within the crystal. For this reason, since the dissipation varies at least as the square of the applied plate voltage, that voltage is kept at a low value. The resistance, R, in the circuit of Fig. 3 is for this purpose.

The vacuum tube circuit of the oscillator with the crystal and temperature control apparatus is shown in the photograph Fig. 8. This whole circuit is mounted in a closed cabinet which itself is temperature controlled by a commercial thermo-regulator.

An important element of this new frequency standard is the submultiple frequency generator which is used as the first element of the system for comparing the rate of the crystal controlled oscillator with the time standard. This submultiple producer consists of an oscillator for generating the low frequency, a harmonic producer for obtaining a harmonic of the low frequency which corresponds to the high frequency by which it is controlled, and a modulator from which is obtained a direct current the amplitude of which is a function of the phase relation between the controlling high frequency current and the harmonic of the controlled low frequency current. The action of the direct current on a control element in the low frequency oscillator maintains the frequency at such a value that the current from the harmonic producer has exactly the same frequency as that from the standard oscillator. Fig. 9 shows the circuit arrangement. The tubes, from the left, are associated with the modulator, the oscillator, the harmonic producer and an output amplifier, respectively.

The control device consists of a core of magnetic material having two windings, one in the oscillating circuit proper and one in the plate circuit of the modulator tube. This coil is designed so that a variation in the direct current output of the modulator causes a variation in the inductance of the winding in the oscillating circuit by virtue of the magnetic saturation of the core.

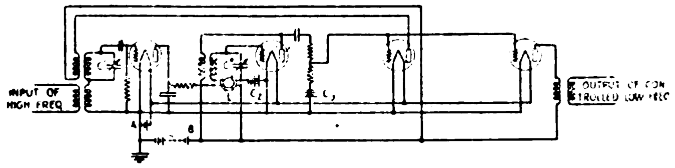

FIG. 9. -- Submultiple Controlled Frequency Generator.

In operating, the low frequency oscillator is adjusted so that the frequency is exactly some submultiple of the control frequency when the direct current into the control coil has a certain mean value. If, then, anything occurs that tends to change the low frequency, the resulting phase shift between the harmonic and the control current instantly causes a change in the direct current in the control coil that opposes that tendency. The result is that, in spite of large variations in the low frequency circuit, the frequency is maintained at an exact submultiple of the high frequency control, the only variation being a slight shift in phase with respect to the control current.

With a circuit operating in this fashion it is possible to control a current so that its frequency shall be maintained in an exact integral relationship to that of some other current, even when the latter is many times higher. A ratio of 50 to 1 may be readily secured with moderate care. It would thus be entirely feasible to secure, by repeated stages, a current having a frequency which was exactly one five-hundredth the frequency of the 50,000 cycle standard, or 100 cycles. This current could then be used to run the synchronous motor of the clock previously described. Actually it has been found advantageous to secure a current having a frequency one-tenth that of the standard and to use this current to operate a 5,000 cycle synchronous motor.

This high frequency synchronous motor operates on the output of a single 5 watt tube.

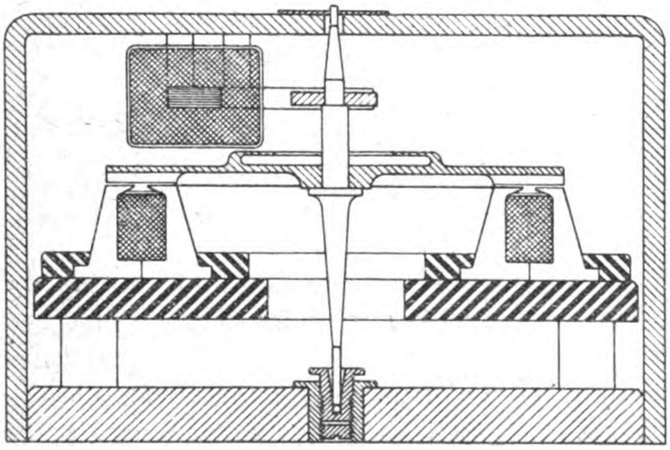

Fig. 10. — Sectional View of 5,000 Cycle Synchronous Motor.

The rotor is mounted on a vertical steel shaft running on a single steel ball under oil. The motor is mounted under a bell jar and is operated in partial vacuum in order to reduce friction losses and to keep the bearings clean. It takes more than half an hour for the motor to come to rest from full speed when it is disconnected from the source of power.

The rotor is a flat disc having 100 teeth milled on one side for poles and having an annular recess in the upper side for the mercury used to prevent hunting. The stator consists of 100 U-shaped pieces of silicon steel arranged in radial planes equally spaced around the axis. These form a ring of the same outside diameter as the rotor, and having an annular space in which is located a coil for magnetizing all the poles in parallel. A single U-shaped piece and a single fin on the rotor constitute one magnetic circuit around the coil. By this construction the minimum magnetic material is used and it is possible to laminate properly every part. Coils can be wound to match the electrical impedance of any suitable vacuum tube and can be exchanged easily. The spacing between the rotor and stator can be altered for any special case by adjusting the lower bearing. Figs. 10 and 11 show a sectional drawing and a photograph of the assembled motor.

The coil of the motor is connected in the plate circuit of the tube used to drive it so that both alternating and direct current flow in the winding. This produces 5,000 magnetic pulses per second instead of 10,000 as would be the case if alternating current alone were used. Thus the rotor moves one pole per complete cycle and revolves at 50 revolutions per second.

Maximum power is obtained in the motor if its impedance is conjugate to the impedance of the output circuit of the amplifier. The internal output impedance of a tube is nearly pure resistance, so the reactive component of the motor impedance is balanced by a series condenser between the motor winding and the filament. The space current is supplied through a choke coil connected to the junction of the motor winding and the condenser. A somewhat better arrangement would be to resonate the motor winding by a parallel connected condenser and to connect the plate battery at a tap in the winding. In this way the choke coil can be dispensed with and the ratio of alternating to direct current in the winding can be adjusted so that the resultant goes to zero once during each cycle. At the same time the impedance of the tube can be matched exactly, as required for maximum power transfer.

It would be a simple matter to arrange a gear train so that this motor might operate the clock mechanism directly. Since, however, there were already available clocks designed to operate on a 100 cycle current, it was thought to be simpler to use these as they were. Consequently, the high frequency motor drives a small generator, the two-pole rotor of which is mounted on the same shaft. Since the speed of the motor is

50 r. p. s., and since the generator is of the inductor type, the generated frequency is 100 cycles — or exactly 1/500th of the original high frequency. The output of this generator is amplified by a single vacuum tube which supplies sufficient power to operate the motor of the 100 cycle clock, the rate of which, there fore, is an accurate measure of the frequency of the 50,000 cycle oscillator.

In the design of the electrical circuits, provision is made for supplying power from multiple amplifiers at 50,000, 5,000 and 100 cycles, which frequencies are in exact harmonic relation. These are available continuously for making frequency comparisons in the three ranges.

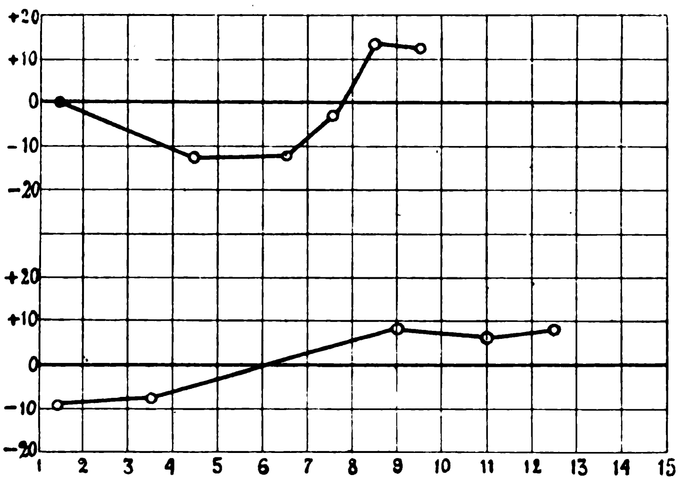

FIG. 12. — Daily Variation in Average Frequency of 50 Kilocycle Standard.

In addition to this provision, circuits have been built that permit the control of any frequency which is a multiple or submultiple up to the tenth order of any one of the three original frequencies. Also, many fractional multiples may be thus controlled. This considerably extends the usefulness of the new standard since it is possible to deliver alternating current at constant frequency over a range from 10 cycles to 500,000 cycles per second. These frequencies are not only constant but are known to the same accuracy as the 50,000 cycle control frequency, being some predetermined exact rational multiple or fraction of that frequency.

Because of the short time during which this standard has been in operation, and because of numerous interruptions for the purpose of making slight modifications, data covering a long continuous run are not available. Measurements made over several brief periods are, however, of interest as they indicate the performance which may be expected from the system. Fig. 12 gives the results of two brief runs. On this chart each point represents the deviation of the average rate for a single twenty-four hour interval from the mean rate for the entire period. It is probable that variations in atmospheric pressure were responsible to a considerable extent for the variations in frequency. It is obviously desirable to provide means whereby the crystal may be operated under constant pressure as well as constant temperature.

The above data indicate a high degree of constancy of the average frequency of this standard over long time intervals. In view of the very great ratio between the rate of the standard and the mean solar day, it is desirable to obtain additional checks as to the constancy of frequency over shorter time intervals. For this purpose a second oscillator, similar to that already described, was adjusted to approximately the same frequency, the actual difference being 0.2 cycles per second. Data taken by measuring the duration of ten consecutive periods at half-hour intervals show the relative variations. The results of these measurements are given in Fig. 13. Each point represents the difference between the ratio of the rates for any one interval from the average ratio of the

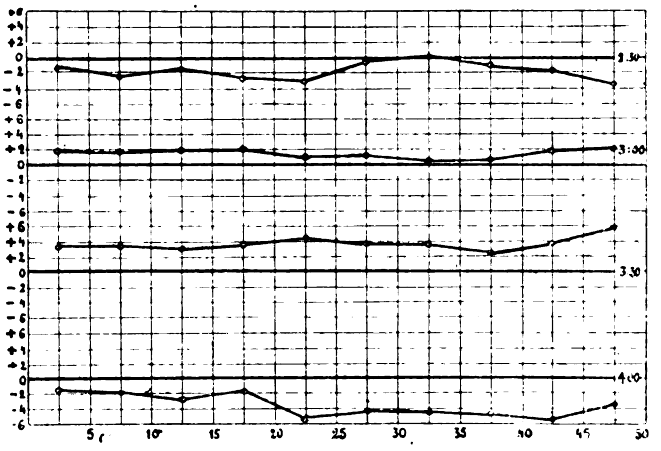

FIG. 13. — Relative Variation in Frequency of Similar Crystal Controlled Oscillators.

rates for the entire two-hour interval. It will be noticed that for some of the runs, particularly that made at three o'clock, the ratio of the rates remains practically constant. At other times, however, as at two-thirty and three-thirty, there is a marked periodicity to the variation. This may be accounted for in terms of temperature variation; the periodicity of the variation is practically the same as that of the operation of the thermostats. Whenever the two thermostats are operated out of phase, there is a noticeable change in the ratio of the rates; whenever they are operated in phase, their rates remain practically constant.

In view of the fact that the accuracy to which a frequency may be defined depends on its constancy, on the precision of comparing its rate with the rate of the earth's rotation, and on the accuracy to which the latter rate can be determined, it seems reasonable, in view of the above data, to expect that in the near future it will be possible to define a frequency at any instant to an absolute accuracy of at least one part in ten million.

It has not been unusual to determine frequency in terms of some other quantity such as the acceleration due to gravity, the velocity of light, or the product of inductance and capacity. These are, of course, indirect measurements because each of the other quantities must first be defined in terms of time. In view of the present accuracy obtainable in the measurement of frequency, however, it is now possible to invert the procedure and measure some of these other physical quantities in terms of frequency with an accuracy heretofore unattainable.

November 16, 1927.

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by E. O. HULBURT,
Naval Research Laboratory, Washington (D. C., U. S. A.)

The more important agencies which may conceivably cause the ionization of the upper atmosphere of the earth are the ultra-violet light, α and β particles, all of solar origin, the penetrating radiation of cosmic origin, and the ionizing radiations from terrestrial sources. The last mentioned may perhaps be ruled out immediately because of the fact that the conductivity of the lower atmospheric strata increases rapidly with the height for the first few kilometers. The possible effects of these ionizing agencies have been considered in papers by Chapman and Milne, Benndorf, Elias, Lassen and others. Recently experiments with the electromagnetic waves of wireless telegraphy together with theories of the propagation of these waves over the surface of the earth have lead to information about the ionization in the upper atmosphere more definite than hitherto obtainable, and it has been of interest to examine again the causes of the ionization.

The experiments of Breit and Tuve with 70 meter waves, of Appleton with 400 meter waves, of Heising with 57 and 111 meter waves, of Wagner and Quack with 15 and 16 meter waves, of Hollingsworth and Eckerslay with long waves, and the experiments of Taylor on the skip distances of waves below 50 meters and the theoretical considerations of Taylor and Hulburt on these skip distances, show that the electron density N increases with the height Z above the earth reaching a value of about 4×10^5; above the height where N has this value the electron density is not known except that it does not go on increasing. Although the wireless data are none too extensive it may be taken that in the day-time (for the North Temperate Zone) the height where N is of the order 10^5 is roughly 150 kilometers, and where N is 10^3 is about 60 kilometers.

Because of the diurnal variation in the ionization we choose the ultra-violet light of the sun as being the ionizing agency deserving first consideration. In order to make an explicit calculation of the ionization the temperature, the pressure, and the constituent gases and their partial pressures must be known at each height in the upper atmosphere. These we may take as given completely in the classical thermodynamic isothermal equilibrium theory of Humphreys, Jeans and others. There is a question as to the existence of hydrogen in the upper atmosphere, but the conclusions given later are much the same whether hydrogen is there or not. The law of the recombination of the electrons with the positive ions must be known. For this we have J. J. Thomson's theory of recombination, and complete formulas are available. We must also recognize the possibility of the electron attaching itself to a neutral molecule, for when it does this, thereby producing a negative ion, it is no longer an energetic refractor of the wireless rays. The oxygen molecule is the only important one in this connection, and the values of the attachment coefficient measured in the laboratory for pressures of 10 mm. of mercury and above must be extrapolated to pressures below 10^{-2} mm., perhaps a questionable extrapolation. The diffusion of the electrons and ions must be considered, this is a very important influence. Using all these things it is concluded that the solar ultra-violet light is a necessary and sufficient cause of the Kennelly-Heaviside layer, and that hypotheses of other agencies of ionization, such as charged particles from the sun, penetrating radiation, etc., are uncalled for except perhaps in unusual cases. Assuming the solar ultra-violet energy to be that of a black body at 6000°K and using known, or estimated, absorption coefficients of the atmospheric gases for ultra-violet waves below λ1300A which cause photo-electric ionization, the electron curve for the sun overhead, i.e. for high noon in summer in the temperate zone, has a maximum of 3×10^5 electrons per cm^3 at a height of 190 km. Below this the ionization can not be calculated exactly, because of the lack of many facts which future laboratory experiments may supply, but a density of 10^4 to 10^5 electrons per cm^3, or 10^9 to 10^{10} ions per cm^3 (or a suitable mixture of ions and electrons) seems possible down to, say, 100 km. This ionization is shown to explain quantitatively many facts of wireless telegraphy, i.e., the skip distances, overhead absorption coefficients, limiting waves, ranges and the apparent heights reached by the waves. Taking into account the seasonal changes in the upper atmospheric pressures and the altitude of the sun, the electron layer for winter noon is found to have a maximum of 1.42×10^5 at a height 147 km, and the ionization below this is less than the summer values by a factor of 2 or so. After sunset the maximum ionization is found to decrease by a factor of about 6 in the small hours of the morning; below the maximum the decrease is greater. These seasonal and diurnal changes in the ionization are shown to be in agreement with the corresponding variations in wireless wave propagation phenomena.

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(1) Abstract of a paper read at the open meeting of the U. R. S. I. at Washington, D. C., October, 1927.

The potential energy of the daytime ionization in a 1 cm^2 column of the atmosphere is found to be at least 1 erg and the assumption that less than 1 % of this is liberated as light will account for the light of the night sky, or the *non-polar aurora*, as Rayleigh calls it. Due to diffusion of the ions along the lines of magnetic force the upper ionic spray of the ionized layer diffuses to the magnetic poles, concentrates there and causes the *aurora*. Calculation indicates that the *ozone* of the atmosphere is perhaps not directly connected with the foregoing ionization, but is formed by longer wave-lengths of ultra-violet light from λ1300 to 1800A.

* * *

An automatic recorder for measuring the strength of radio signals and atmospheric disturbances,

by E. B. JUDSON,
Laboratory for Special Radio Transmission Research,
Bureau of Standards,
Washington (D. C., U. S. A.)

The recording system described was designed for the purpose of obtaining knowledge of the behavior of radio signals over considerable periods without the presence of an observer. With the apparatus used it is possible to obtain hourly observations of the field strength of several stations and atmospheric disturbances throughout the twenty-four hours.

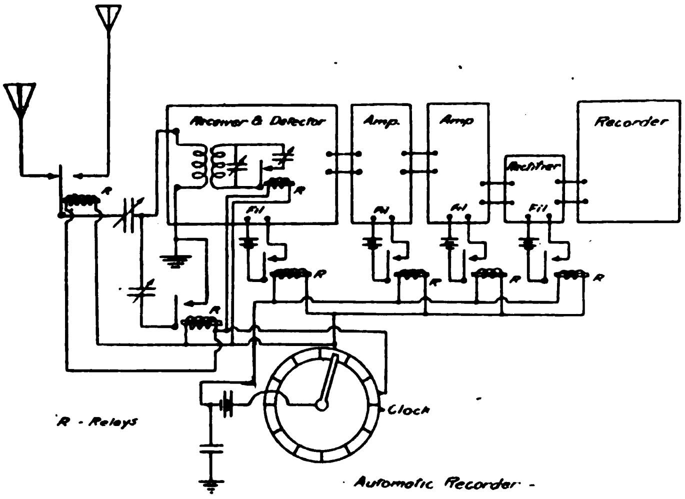
The entire apparatus is controlled by a clock, which, at different five-minute periods during the hour actuates a series of relays automatically turning on the receiving set and amplifiers and tuning to the desired stations.

Figure 1 shows the schematic diagram of the circuit and figure 2 shows the arrangement of the apparatus.

The receiving set is of the conventional autodyne type with two tuned circuits having a tuning range from 60 kc. (5,000 m.) to 12,0 kc. (25,000 m.). Two antennae are used, one having an effective height of 16 meters for reception of transatlantic stations and atmospheric disturbances, while the other having an effective height of 1^m5 is used for nearby American stations.

In order to insure greater constancy of sensitivity, only audio-frequency amplification is used. This consists of two stages of transformer coupling followed by four stages of resistance-capacity coupling. With this arrangement, as long as all the filament currents remain constant and the plate voltages do not change the system retains its calibration with sufficient accuracy (within 10°/₀) over periods of several months.

The last audio-frequency amplifier is coupled to a rectifier circuit, containing the recording galvanometer, through an air core audio-frequency transformer. A three-electrode tube having the plate and grid connected is used for rectification. Generally, tubes used in this manner give a slight galvanometer deflection, when no signal is present, due to the initial velocity of the electrons. This current, however, can be balanced out by a reversed E. M. F. across the galvanometer if it is comparable to the current received from signals.



Automatic Recorder - Laboratory for Special Radio Transmission Research - Bureau of Standards.

FIG. 1.

Records of the variation of signals and atmospherics are made with a Cambridge-Paul Thread Recorder.

This instrument is essentially a sensitive recording galvanometer having a moving coil arranged to give a series of instantaneous records of the galvanometer deflections. The moving coil of the galvanometer has attached to it a pointer which overhangs the drum carrying the paper, while between the pointer and the drum an inked thread is stretched parallel to the axis of the drum at a short distance above its surface. A presser bar is situated above the galvanometer pointer which is normally held free of the pointer by a cam and its follower. At regular intervals the cam makes a half revolution, first allowing the presser bar to fall upon the pointer and immediately raising it to its normal position. As the presser bar falls it depresses the pointer on the drum nipping the inked thread between the pointer and the paper producing a dot on the paper, which makes a visible record of the deflection of the galvanometer at the moment. The drum of the recorder is arranged for two speeds, one giving a complete revolution in twenty-four hours and one giving a revolution every two hours for short time records. For the present purpose the twenty-four hour revolution is used.

The clock controlling the entire system has its face plate equipped with twelve brass segments arranged in a circle, each segment representing five minutes. A spring on the end of the minute-hand makes an electrical connection with each segment as it passes over.

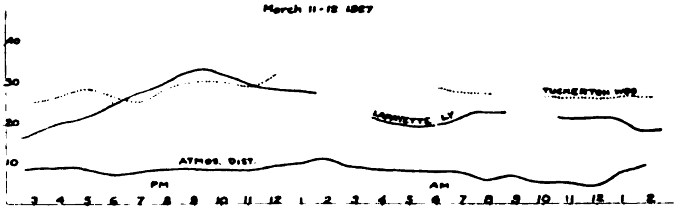


FIG. 3.

The cam allows the presser bar to depress once every thirty seconds, making ten dots on the paper for one five-minute segment.

For the present purpose, the first five-minute segment in the hour is connected so that when the minute-hand contact passes over it, a relay closes, turning on the receiving set, tuned to the station having the highest frequency of those to be measured. The amplifiers, the rectifier tube and the presser bar control are switched on simultaneously by means of other relays.

The following segments operate the same relays as the first, but are arranged to close other relays which connect parallel variable capacities across the primary and secondary tuning capacities of the receiving set. This allows the receiver to be tuned to other frequencies effective only for a certain clock segment.

The entire system is slightly sensitive to change of tone. The pitch of the signals being recorded is therefore set to 1,000 cycles by comparison with an electrically-driven 1,000-cycle tuning fork. A 30 ohm damping resistance across the galvanometer coil slows its period so that it is little affected by change of speed in transmission. Absolute calibration of the receiving set is obtained from a radio-frequency oscillator feeding into the antenna circuit, while the amplifiers and rectifier may be checked at any time by connecting them to the output of the telephone comparator (1).

The deflection-current curve of the galvanometer is nearly straight over the usual range of observations. As a protection against heavy atmospherics the deflection is limited just below full scale by limiting the output of the last amplifier tube.

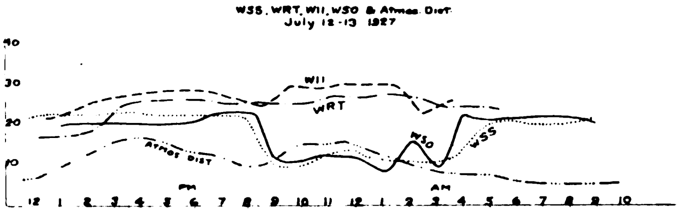


FIG. 4.

Continuous records of several stations and atmospheric disturbances have been made at the Laboratory for Special Radio Transmission Research of the Bureau of Standards since February, 1927. During the winter months when atmospheric disturbances were low, records were made of Lafayette (LY) and Rugby (GBR) along with Tuckerton (WGG) or Rocky Point (WSS). During the heavy static season, measurements were confined to four American stations, namely, two New Brunswick stations (WII and WRT), Rocky Point (WSS) and Marion (WSO), reception being on the small antenna. The large antenna, however, is used for reception of atmospheric disturbances.

Figure 3 shows a typical twenty-four hour record of Lafayette (LY), Tuckerton (WGG) and atmospherics at 12 kc. (25,000 m.).

In figure 4 are given typical twenty-four hour summer curves, of WSS, WRT, WII, WSO and atmospherics which show in the case of WSS and WSO an apparent interference of the reflected and direct waves during the night.

* * *

Experiences in Radio Compass Calibration,

Abstract of paper by F. A. KOLSTER,

Chief Research Engineer, Federal Telegraph C°,
Palo Alto (California, U. S. A.)

The radio compass is now generally accepted by the navigator as an accurate and important navigational instrument. Due to the fact that the radio compass, when installed on board ship, is necessarily located in the midst of a complicated metallic network in which currents are set up by the electromagnetic radiation from the signaling station, a calibration must be made in order that the proper correction may be applied to the observed bearing.

Deviation from the true bearing is caused by the effects of the metallic mass of the ship and experience has shown that this deviation follows very closely a sine curve, assuming positive values over the starboard bow and port quarter and negative values over the port bow and starboard quarter.

Accuracy is dependent upon the permanency of the calibration and it is important, therefore, that the large conducting system, made up of masts, stays and rigging, remains the same at all times. Long stays should be thoroughly insulated to avoid large electrically closed loops and mast guys should be well bonded to the ship's hull to avoid varying electrical effects.

This problem should be understood by naval architects and ship builders in order that proper consideration may be given to the rigging of ships from the point of view of the resulting effects upon the performance of the radio compass.

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(1) *Proc. I. R. E.*, vol. 12, n° 5, p. 521; 1924.

A theory of the upper atmosphere and meteors (1),

by H. B. MARIS,

Naval Research Laboratory, Washington (D. C., U. S. A.)

The force of gravity acting on the atmosphere of the earth causes the heavier gases to settle downward and the lighter gases to rise to higher altitudes by diffusion and winds unhindered by diffusion would by convection keep the composition of the air uniform at all elevations. The classical ideas of the change in atmospheric pressure with altitude (e. g. Humphrey, Jeans, Chapman and Milne, etc.) have been based on the assumption that convection is negligible, at least in the upper atmosphere, and that each gas was through diffusion in gravity equilibrium with its own partial pressure. Investigation has shown, however, that diffusion is of importance only at elevations greater than 100 kilometers.

The ordinary equations of diffusion show at once that if the air were uniformly mixed at all altitudes and then left free from all convection currents, there would be a constant flow of lighter molecules upward and of heavier molecules downward, which would be independent of the altitude until a level was reached where the diffusing gas would be in gravity equilibrium. This « diffusion » level for hydrogen would move from infinity down to 142 kilometers in one day, at the end of five days it would be at a height of 127 kilometers and in 50 days it would be at 113 kilometers. The corresponding levels for helium would be at 137, 120 and 106 kilometers respectively. The new calculations give hydrogen and helium contents above 150 kilometers roughly 1/100,000 of the values previously calculated.

Recent use of the upper atmosphere as a medium for transmitting electromagnetic radiation of wavelength 10 to 10,000 meters has emphasized the importance of knowledge or at least of a theory of changes which occur in the upper atmosphere between day and night conditions during different seasons of the year. Absorption of solar and terrestrial radiation by the air must determine any theory of temperature distribution in the upper atmosphere. Humphrey has discussed this problem and has suggested that it should have been worked out but no attempt has been made previously to apply radiation and absorption coefficients and solve for the thermal condition of the upper atmosphere or to estimate probable temperatures at elevations greater than 20 kilometer for the radiation conditions of day and night or winter and summer.

Water vapor above 11 kilometers absorbs a little over 20 °/₀ of black body radiation from below at earth temperatures while carbon dioxide absorbs nearly 40 °/₀. Ozone absorbs only about 2 °/₀ but its presence is important because it absobs about 4 °/₀ of the solar radiation at an altitude where most of the reradiation must be by the ozone itself. Temperature calculations based on these absorption coefficients show that for a 50° latitude above a height of sixty kilometers we should expect a temperature of about 250° K during a winter day with a drop to 220° during the night and a temperature of 370° during a summer day with a corresponding drop to 230° during the night. The atmosphere at the base of the stratosphere cannot be in radiation equilibrium but must receive more radiant energy than it looses both from above and below during a twenty-four hour day. The loss in heat by radiation from the warm equator is much less than from the cooler polar regions. An increase in temperature at sea level near the equator would not result in an increase in the energy lost by radiation from these regions, but would actually result in a decrease. Loss of heat by radiation from the earth depends, not on the condition of the surface, but on the temperature at the base of the stratosphere and absorption in the stratosphere. The temperature condition of the earths surface is in very unstable equilibrium. A slight change in the carbon dioxide of the air would have a termendous influence on the climate of the earth. If the carbon dioxide content of the air were increased from the present 0.03 °/₀ to 0.1 °/₀ tropical plants would probably grow in the polar regions. On the other hand if this protecting sheet decreased from 0.03 °/₀ to 0.01 °/₀ ice would probably be found near the equator.

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(1) Abstract of a paper read at the open meeting of the U. S. R. I. at Washington, D. C., October 1927.

Since the present theory leads to low densities of the atmosphere above heights of 100 kilometers, densities one hundred thousandth of those of classical tables at 300 kilometers, the facts about the appearances of meteors require explanation. It seems possible to do this following to a certain extent the ideas of Sparrow and to a certain extent those of Lindemann. When a high speed meteor strikes an air molecule, it is assumed that the energy of the impact violently ejects atoms, molecules and possibly small particles of molecular dimension from the body of the meteor. This ejected material by virtue of its velocity carries into the air the energy which eventually gives the light of the meteor trail. For example, when a nitrogen molecule strikes an iron meteor which has a velocity of 40 kilometer per second, the energy of the impact is sufficient to raise the temperature of 1,800 molecules 1,000° C or to evaporate 56 molecules of iron, or to evaporate and ionize 24 molecules of iron. As a result of this impact a mass many times that of the nitrogen molecule is ejected from the meteor principally in the form of highly energized iron atoms which have velocities slightly greater than that of the meteor itself. The inelastic collisions of these iron atoms with the molecules of the air result in the visible trail. The excitation energy of these collisions may be as high as 155 volts for nitrogen or 280 volts for argon. Much of this energy may be radiated in the ultra-violet or even soft x-ray region, and it is probable that not more than one-tenth of the total radiation is in the visible part of the spectrum. Therefore, the total mass of the meteor must be much more than that derived by Lindemann and Dobson from their considerations of the relation between the mass of a meteor and its light. The temperature changes in the upper atmosphere from evening to morning, and from winter to summer, given by the present theory lead one to expect appearance of meteors at heights which are greater by say 5 kilometers in the evening than in the morning and in the summer than in the winter. It would be interesting to know whether this difference has been observed.

Recent studies of the propagation of electromagnetic waves over the earths surface have emphasized the need of a theory and definite conclusions concerning diurnal and seasonal changes in temperature and composition of the atmosphere at heights greater than 50 kilometer. It was the purpose of this discussion to take what steps were possible toward the meeting of this need.

Naval Research Laboratory,
« Bellevue », Washington, D. C.
1 November 1927.

* * *

Note
au sujet des ondes de quelques mètres,

par René MESNY.

Dans ces dernières années, nous avons eu l'occasion de faire, en collaboration avec MM. Beauvais et David, une série d'expériences avec des ondes de longueurs comprises entre 2 et 4 mètres. Ces expériences ont permis de fixer les propriétés de ces ondes et leurs conditions d'utilisation; nous les résumons ci-dessous.

Emission et réception. — Le générateur a toujours été du type symétrique (1) à deux triodes; la puissance d'alimentation a varié entre 2 et 200 watts.

L'antenne était le plus souvent demi-onde, mais nous avons aussi employé des antennes de plusieurs demi-ondes et même des antennes absolument quelconques comme celles des navires sur lesquels nous avons travaillé.

La réception a toujours été une superréaction dont l'emploi s'est montré avantageux et pratique.

Propagation loin du sol. — Entre deux points qui se voient l'un l'autre, les transmissions sont excellentes à toutes distances, même avec les plus faibles puissances. Dans les Alpes, entre deux sommets dont la distance était de 100 kilo-

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(1) R. Mesny, *Les Ondes électriques courtes,* p. 61.

mètres, nous avons réalisé des communications téléphoniques duplex parfaitement sûres avec des postes portatifs à piles dépensant 3 watts pour l'alimentation de l'émetteur. Dans d'autres circonstances, nous avons atteint jusqu'à 280 kilomètres, la réception restant encore extrêmement forte quoique l'émetteur et le récepteur ne soient plus tout à fait en visibilité.

Il n'y a d'ailleurs rien qui puisse étonner dans ces résultats; ils sont dus tout simplement à ce que l'énergie est parfaitement utilisée pour le rayonnement avec ces ondes très courtes. Si W est l'énergie rayonnée en watts et D la distance en kilomètres, le champ à cette distance est, en microvolts par mètre,

$$\mathcal{E}^{\frac{\mu V}{m}} = 6700 \frac{\sqrt{W^{w}}}{D^{km}},$$

en supposant que l'émetteur soit isolé dans l'espace et qu'il n'y ait pas d'amortissement. Un seul watt rayonné donne donc, à 100 kilomètres, un champ de $67 \frac{\mu V}{m}$.

Influence des écrans. — Quand il existe un écran entre l'émetteur et le récepteur, les signaux sont d'autant plus atténués que la hauteur de cet écran est grande, et ils ne tardent pas à s'annuler quand elle croît. Nous avons fait plusieurs expériences en pays de montagnes en intercalant entre l'émetteur et nous-même l'écran formé par une chaîne de collines situées à des distances de 20 à 30 kilomètres. En nous déplaçant sur une pente opposée à l'émetteur nous pouvions, soit nous mettre en visibilité de ce dernier, soit pénétrer plus ou moins profondément dans son ombre géométrique. Dans tous les cas, les signaux ont disparu assez brutalement au moment où la ligne joignant le récepteur au bord de l'écran faisait avec celle qui allait directement à l'émetteur un angle de 1° à 1°,5. Aucune mesure quantitative n'a encore pu être faite, et la rapidité avec laquelle on voit disparaître des signaux forts dépend beaucoup des récepteurs employés; cependant, nous avons l'impression que la diminution des signaux était plus brutale que ne l'indiqueraient les formules d'optique relatives à la diffraction par un écran rectiligne.

Propagation près du sol. — Dans le voisinage d'un sol plan les choses peuvent complètement changer d'aspect.

Tout d'abord si l'émetteur et le récepteur sont tous deux à quelques mètres d'un sol plan, ou à peu près plan, sur une grande étendue, les communications faites avec une puissance de 3 watts et qui étaient excellentes à 100 kilomètres entre deux sommets, deviennent médiocres à 1,5 kilomètre; les signaux disparaissent complètement entre 2 ou 3 kilomètres.

Mais, il n'est pas nécessaire que l'émetteur soit près de ce plan, il suffit que le récepteur le soit. Nous avons fait de nombreuses expériences en plaçant l'émetteur au sommet de la tour Eiffel et en nous promenant avec le récepteur dans la région parisienne. Chaque fois que nous nous trouvions sur un sommet les signaux étaient extrêmement forts à toutes distances. Au contraire, dès que le récepteur était sur un plateau, les signaux disparaissaient quand la distance était supérieure à 20 kilomètres environ. Si l'on allait se placer sur le bord du plateau situé du côté de l'émetteur, les signaux redevenaient forts; à 400 ou 500 mètres de ce bord, souvent même à 200 mètres, ils disparaissaient entièrement ou presque entièrement.

La première idée qui vient à l'esprit est de voir dans ce phénomène un effet de l'absorption du sol. La brutalité de l'affaiblissement quand on s'éloigne du bord de la falaise nous a fait chercher une autre explication. Il nous a paru difficile qu'en 400 ou 500 mètres l'énergie de l'onde puisse être absorbée à ce point. Les formules de Zenneck invoquées souvent en la circonstance ne nous paraissent pas applicables: elles concernent une onde qui a pris un régime permanent à la suite d'un parcours obligatoirement long au voisinage du sol, assez long pour que le champ électrique ait acquis une composante horizontale importante, pour que l'onde se soit inclinée en avant (cette dernière image est d'ailleurs peu précise en raison de la rotation du champ). Si l'on peut chercher à justifier une telle explication dans le cas où émetteur et récepteur sont près du sol, il n'en est pas de même quand l'émetteur est très élevé; comme il est en même temps relativement éloigné, on peut admettre que les ondes qui arrivent au récepteur sont des ondes planes, et quand ce récepteur est sur un plateau, on est en présence de la réflexion d'une onde plane sur un plan. C'est un problème classique et l'on trouve facilement que dans les conditions de la pratique (constante diélectrique et conductivité normales) la réflexion se fait avec changement de phase de près de 180°, si l'angle du sol avec les rayons est faible. Quand cet angle est d'un demi-degré, par exemple, le champ résultant à quelques centaines de mètres du bord d'un plateau est environ vingt-cinq fois plus faible qu'au bord où la réflection ne joue pas. Nous pensons que telle est la cause du phénomène observé.

Ce qui nous confirme dans cette opinion, c'est qu'après avoir déplacé l'émetteur et l'avoir installé sur un sommet d'une hauteur de 175 mètres (mont Valérien), nous avons pu obtenir des signaux encore très convenables, à plusieurs kilomètres du bord d'un plateau dont l'altitude était voisine de 200 mètres (au sud de Beauvais) et situé à une cinquantaine de kilomètres de l'émetteur. Il n'y avait plus d'onde plane réfléchie, mais un phénomène de diffraction. Les énergies en jeu étaient d'ailleurs du même ordre que quand l'émission se faisait du sommet de la tour Eiffel (150 watts alimentation environ).

Ces phénomènes n'ont peut-être pas d'importance pratique; ils paraissent néanmoins intéressants, en faisant ressortir différents modes de propagation.

Propagation aux grandes distances. — Des essais très soignés, exécutés dans des conditions très favorables, avec une puissance d'émission de 150 watts alimentation, ne nous ont donné aucun résultat à des distances de 600 et de 900 kilomètres. Quoique l'émetteur fût encore au sommet de la tour Eiffel, on était extrêmement loin de la visibilité théorique : L'horizon visible de la tour Eiffel est de 65 kilomètres seulement, et à une distance de 600 kilomètres la rotondité de la terre crée un écran d'une hauteur de 7 kilomètres. La réfraction ionique seule pourrait permettre de telles communications, et l'on sait qu'elle paraît insuffisante pour ramener au sol, même à des distances beaucoup plus grandes, des ondes d'une longueur inférieure à une dizaine de mètres.

Utilisation des ondes de quelques mètres. — L'utilisation pratique des ondes de quelques mètres est aussi simple que celle des ondes plus longues. Les petites puissances qui suffisent à couvrir les distances accessibles se réalisent très facilement; les antennes peuvent être quelconques, mais quand on emploie des antennes demi-onde on arrive à réduire l'encombrement dans des conditions fort avantageuses pour les usages pratiques. L'emploi de la superréaction pour la réception supprime toutes les difficultés qui pourraient provenir de l'élévation de la fréquence. Les atmosphériques sont absolument insensibles.

L'influence radicale des écrans donne à ces ondes une qualité de discrétion qui n'existe pour aucune autre gamme, et cette qualité peut être notablement accrue par l'emploi de systèmes directifs dont l'établissement est particulièrement facile.

Enfin, grâce à la réduction d'échelle, ces ondes permettent de faire très simplement de nombreuses expériences qui sont difficiles ou impossibles avec les ondes plus longues. Nous signalerons à ce sujet les mesures que nous avons effectuées sur divers systèmes directifs et en particulier sur les rideaux d'antennes en grecque. Cette disposition, imaginée par Chireix (1) et par nous-même (2), permet d'obtenir une concentration considérable d'énergie par les moyens les plus simples.

* * *

A Note on the Short Wave Long Distance Transmission,

by T. MINOHARA and K. TANI,

Naval Experimental and Research Establishment,
Tokyo (Japan).

It is well known that the path of propagation of short waves over long distances, depends on the position of the so-called Kennelly-Heaviside

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(1) Société Française Radioélectrique. — Brevet français, n° 216,757, 10 mars 1926.

(2) R. Mesny, Émissions dirigées par rideaux d'antennes en grecque. (*Onde électrique*, 6 mai 1927, pp. 181-200.)

layer which varies with day-time and season. Consequently, it is not simple to treat the phenomenon on the transmission over long distances, as the height of Kennelly-Heaviside layer is not the same at different localties where the time and season are quite different.

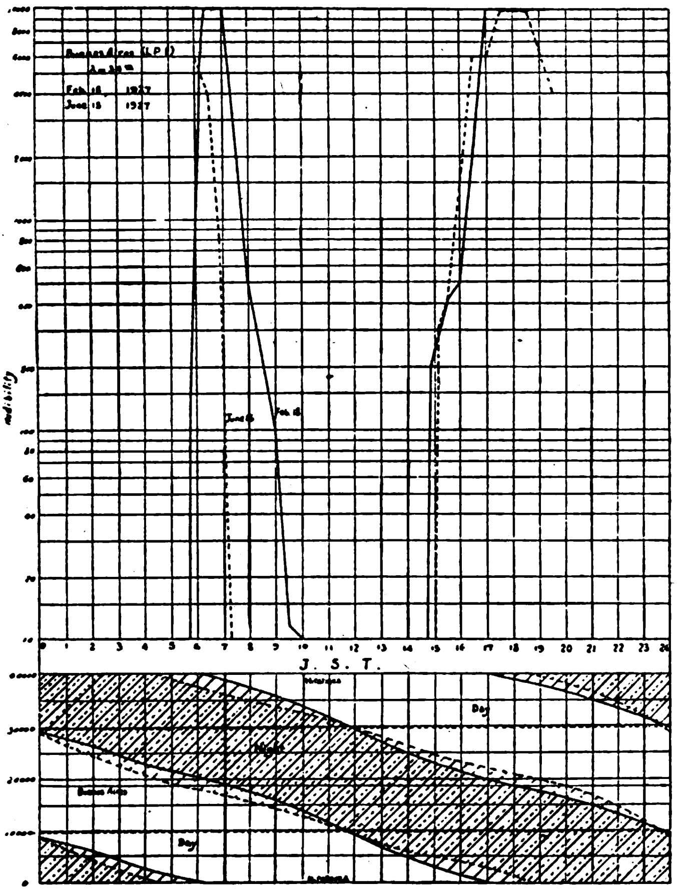

Fig. 1.

To study the experimental results of short waves in long distance communication, we take the following method which is very convenient to trace the course of the wave.

Plot the hours in abscissa, and the distance along the great circle between the stations in ordinate, as shown in the lower part of the Figs. 1 and 2.

Draw the boundary line of day and night. Then we can easily investigate the relation between the path of waves, and the darkened space.

Further we can suppose that the conductivity of the upper atmosphere as noon is not the same as right before the sun set or right after the sun rise. If we assume that the height of the conducting layer of the upper atmosphere is inversely proportional to the cosine of the angle of altitude of the sun at the locality to be considered, we can calculate and plot the curve representing the curvature of Kennelly-Heaviside layer as shown in Fig. 3.

Let us now explain some typical experimental data with the aid of the above consideration.

The Fig. 1 shows the test result of the signal intensities of short wave ($\lambda = 34$ m) sent by the station at Buenos-Aires (L P I), and received at our laboratory in Hiratsuka near Tokyo, on February 18th and June 18th 1927.

It is clear from the figure that the signals are strong twice a day in the period where the night signals travel along the shortest distance of darkened space in the opposite side of each other.

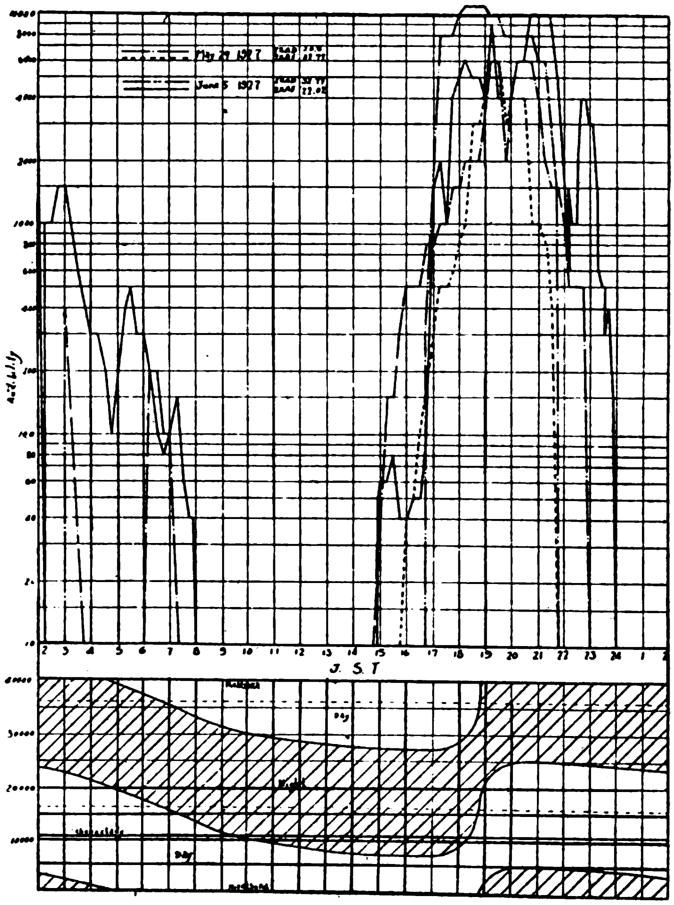

Fig. 2.

Fig. 2 shows the test result of the signal intensity of short wave sent by the station XAF Schenectady, and received at Hiratsuka.

It is a remarkable that the signals of the wave length 26.8 m are strong at 3.00 A. M.

and 6.30 A. M. J. M. T. In Fig. 3, ABA' represents the great circle containing the receiving station A and the sending station B developed into a straight line. *ll'*, whose height above ground is *h*, shows the level of Kennelly-Heaviside layer at the night-time, and DD', whose height is *h'*, shows the level of the layer at noon when the ionization is the most intense. Thus the conducting layer at any instant when the ray strikes at some angle of inclination, must lie between *ll'* and DD'. Plotting the position of the layer calculated under the assumption mentioned above, we get the curves of 3-00, 4-45, 6-30, 9-00, 14-00, 19-00, J. M. T. respectively as shown in broken line in the Fig. 3.

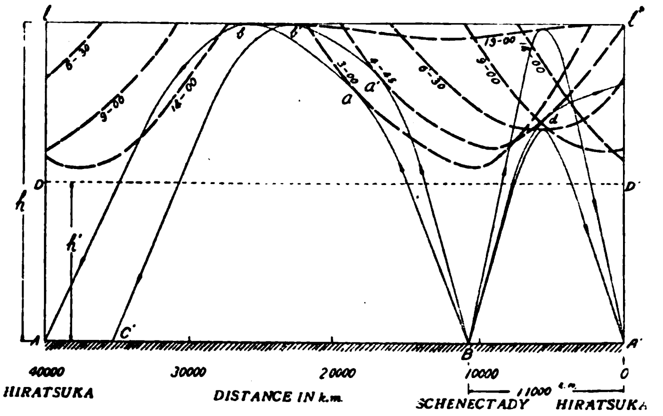

FIG. 3.

The problem on the path of the wave propagation can neither be solved by pure reflection nor by pure refraction, only, but generally it may be supposed that the ray is refracted gradually along the curvature of the globe and refracted abruptly or practically reflected downward at the conducting layer and return towards the earth. For the sake of simplicity, we reduce the process to pure equivalent refraction in the graphical representation supposing the earth surface to be a plane. Then we get the trace of the path of the wave B*ab*A for 3-00 J. M. T. and B*d*A' for 6-30, J. M. T., therefore the signal can be received at the station A, but during the other period 4-45, J. M. T. for example, we can not receive the signal, as the wave travels along the path B*a'b'c'* or B*d*.

Fig. 4 shows the intensity of signal sent by the station Nauen, received at Iwatsuki. Similar remarkable fact can be seen in these results and the same explanation as above mentioned can be applied, as shown in Fig. 5.

As there are many assumptions and other unknown factors are involved in these treatments, it should be not so simple in actual case but they may be looked upon as new suggestions taking account the present knowledge of radio engineering.

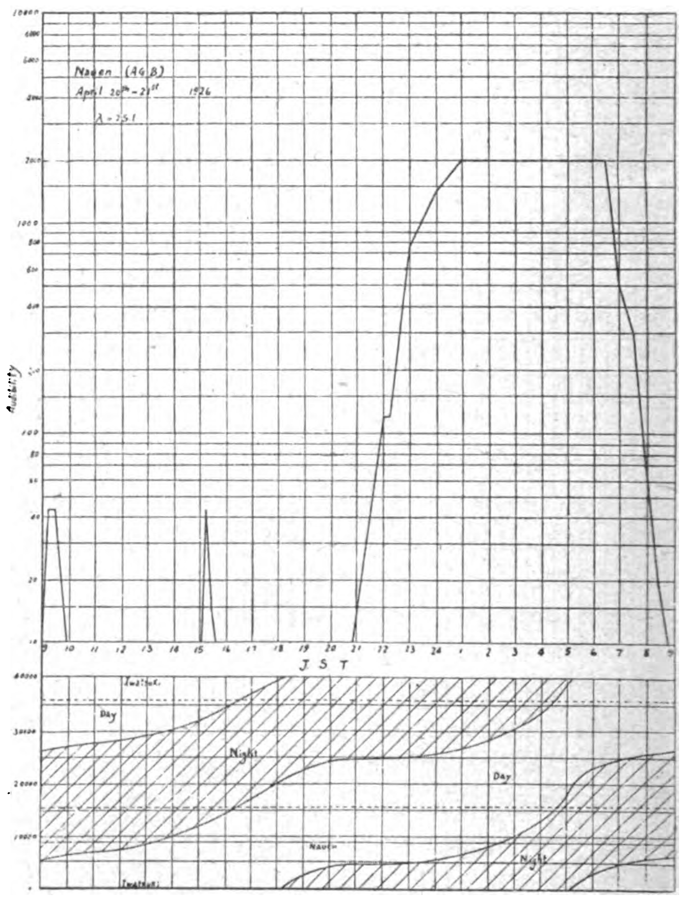

FIG. 4.

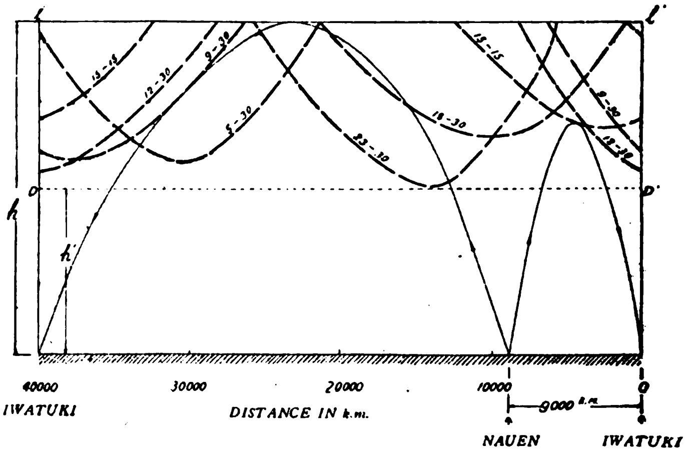

FIG. 5.

* * *

Diurnal Variation in Signal Strengths of Short Waves,

by T. NAKAGAMI and T. ONO,
Direction General of Telegraph and Telephone Engineering,
Ministry of Communications, Tokyo (Japan).

Many theories on short wave transmission phenomena have been proposed and the test results of the measurements on short wave signals reported, giving valuable contribution to our knowledge on the propagation of radio waves.

In examining these reports, we must take into consideration what waves were employed, in what season and at what hours the tests were carried out, and what was the distance between the sending and receiving stations, as these factors are intimately connected, although the mutual relations are complex.

During the past two years, we conducted several tests in order to find out the best wave length in the day-time or night-time transmission during some season for a certain distance in Japan.

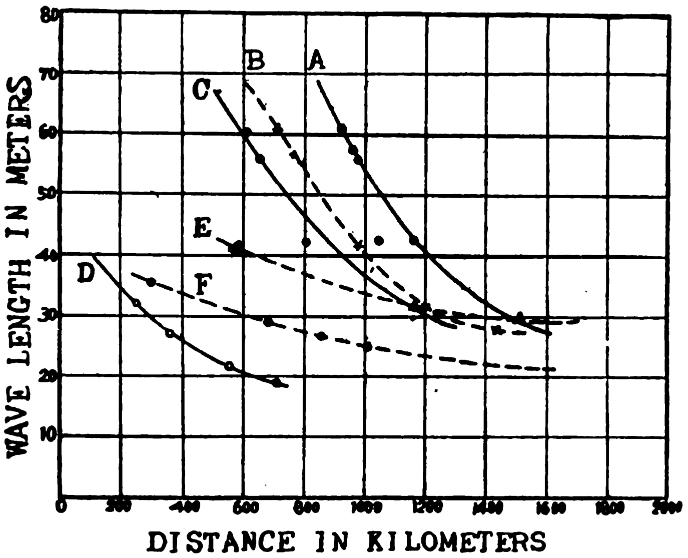

Fig. 2.

One of our tests was carried out at the beginning of January, 1927. A short wave transmitter was installed at Kagoshima Radio Station, and the antenna was of the simple V shape and its power about 500 watts, the natural wave length being equal to that of sending. The receiving stations were selected at different places, so that we could get sufficient data at different distances. At each place a short wave receiver consisting of a detector and one stage audio-frequency amplifier was installed.

We sent test signals during 24 hours on several different wave lengths at Kagoshima, and they were received at eight receiving stations simultaneously. Thus we got the results given in Fig. 1 which shows the diurnal variation in signal strengths with respect to the wave lengths and distances. From these curves we may observe the following interesting facts :

1. In night-time, the 61 m wave is unreadable at short distances, but as the distance becomes greater the signals get stronger and the hours of readability become greater.
2. The skip distance of a certain wave is greater in night-time than in day-time and the shorter wave skips more than the longer one.
3. As the wave length becomes shorter, the hours of readability in night-time get less and less at a short distance but the hours of readability on the same wave length become greater with increase in distance.
4. It seems that there are optimum day-time and night-time wave lengths at a definite distance and that the greater the distance, the shorter the optimum wave lengths. This will be described later.
5. Peculiarity in the transmission of the shorter waves along the meridian for a certain distance on a certain wave length is that the signals are unreadable except for a few hours at the sundrise and sunset. The reason of this fact seems that in the day-time the signals are absorbed and become unreadable owing to the low power and in the night-time the signals skip over this distance and at the sunrise and the sunset the altitude of the ionized layer or the degree of ionization in the upper atmosphere is favorable for the transmission on that wave length to that distance.

We also made several tests on short waves to find the optimum wave length for a given distance. One of the tests was conducted in June, 1926.

The test signals sent from Tokyo on different wave lengths were received simultaneously at several places, and we found out the wave length which can be received for 24 hours at a certain point, though this wave was neither the best one for the day-time nor for the night-time.

The result is given in the following table and in Fig. 2, Curve F :

Sending Station	Tokyo.				
Receiving Station	Kanagawa.	Hiroshima.	Sapporo.	Otchishi.	Kagoshima.
Distance between Sending and Receiving Stations in Km	300	360	890	965	965
Wave length in meters which gives all day signals.	35	29	28	25	25

Another similar test was carried out in January, 1927, and we got the following result :

Sending Station. . .	Kagoshima.	Sapporo.	Kemikawa.	Kagoshima.	Kagoshima.	Osaka.	Kemikawa.
Wave length. . . .	61	75	56	4.28	41.5	32	27.5
Receiving point where the signals were readable throughout 24 h.	South of Naha. South of Kanazawa.	Hiraiso. Iwatsuki.	Hiroshima. Sapporo.	Iwatsuki.	North of Kanazawa.	Naha.	South of Naha.
Distance between Sending station and the Receiving point. .	700	780	800	985	900	1,170	1,550

Curve B, in Fig. 2 is plotted from the above table. Besides these, the other curves in Fig. 2 show the results obtained by similar tests carried out in Japan; i.e., Curve A is the day-time maximum range of the 500 watt transmitter in winter; Curve D, the skip distance of day-time; Curve C, that of night-time in winter; and Curve E, the wave lengths which may be used throughout day and night in spring. If we want to select the optimum wave length for commercial services, we must make use of Curves B, E and F in winter, spring and summer respectively, taking into consideration the fact that the optimum wave length at night is a few meters longer than that given by the curve, while the best wave length in day-time is a few meters shorter.

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FIG. 1 - A

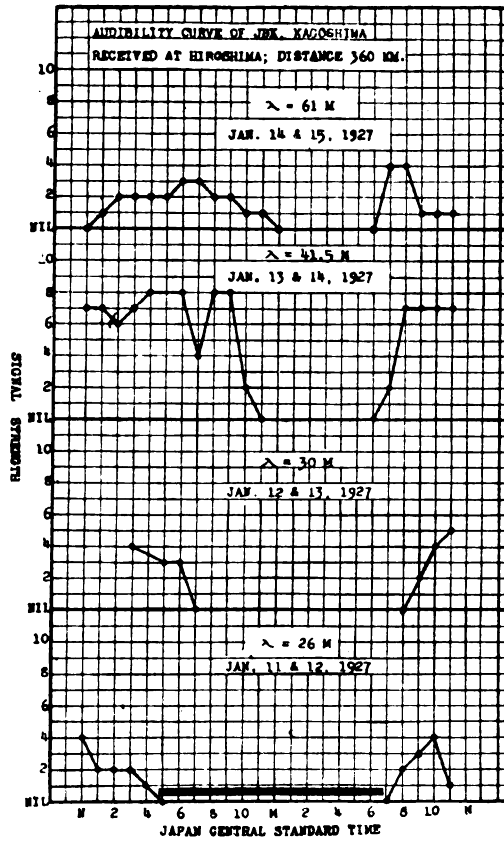


FIG 1 - B

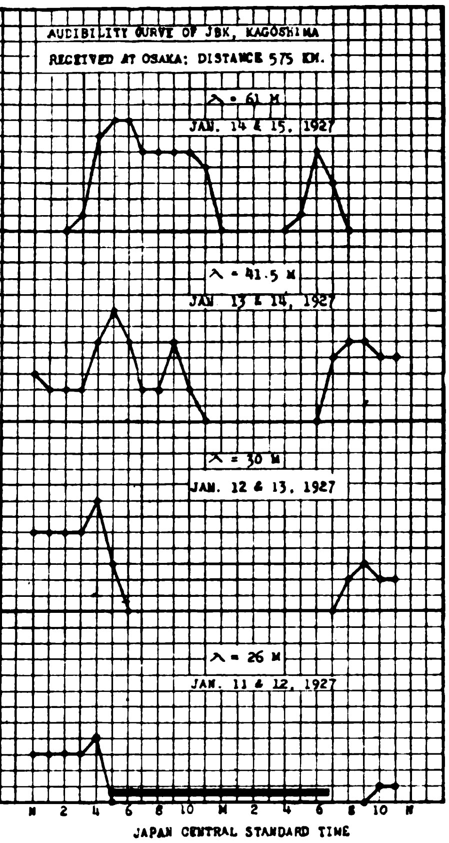


FIG. 1 - C

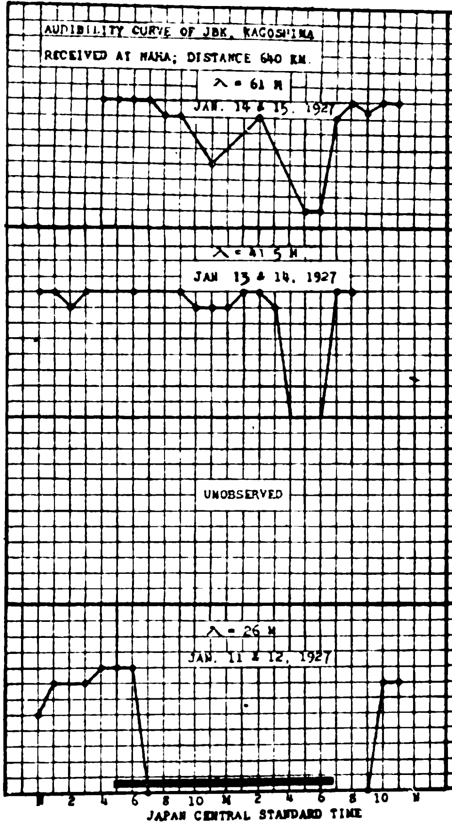
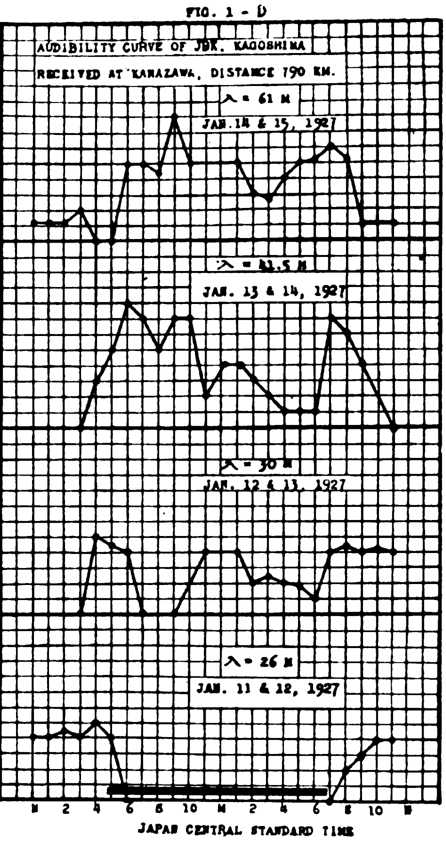


FIG. 1 - D



T. NAKAGAMI and T. ONO.

FIG. 1 - E

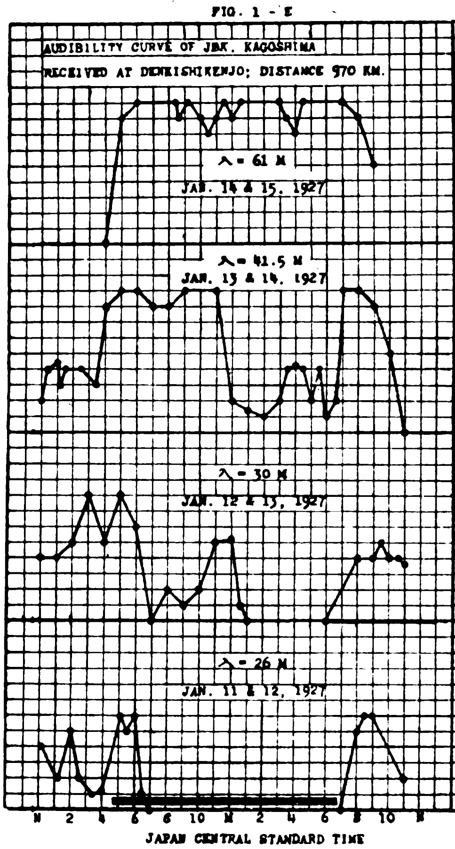


FIG. 1 - F

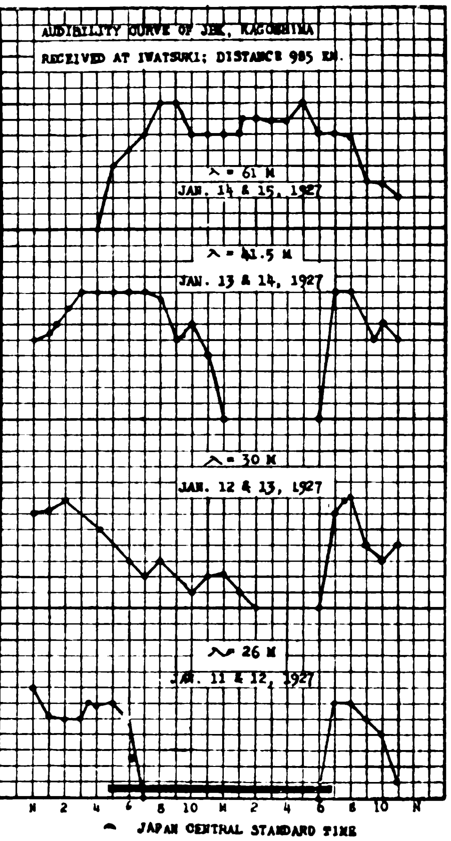


FIG. 1 - G

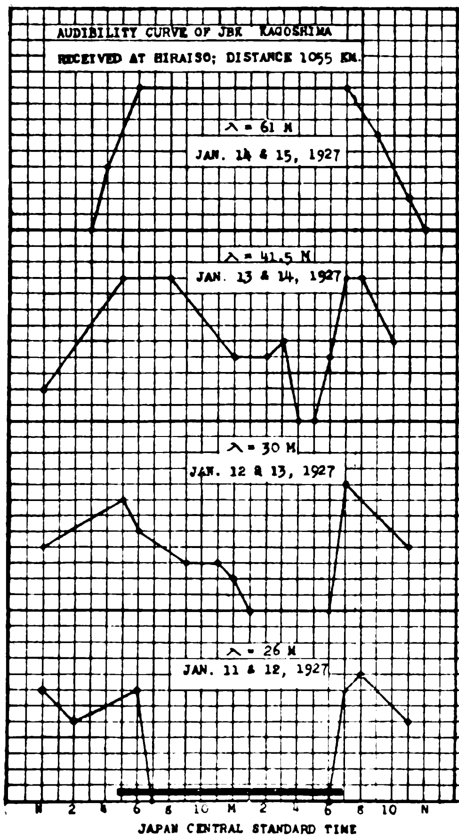
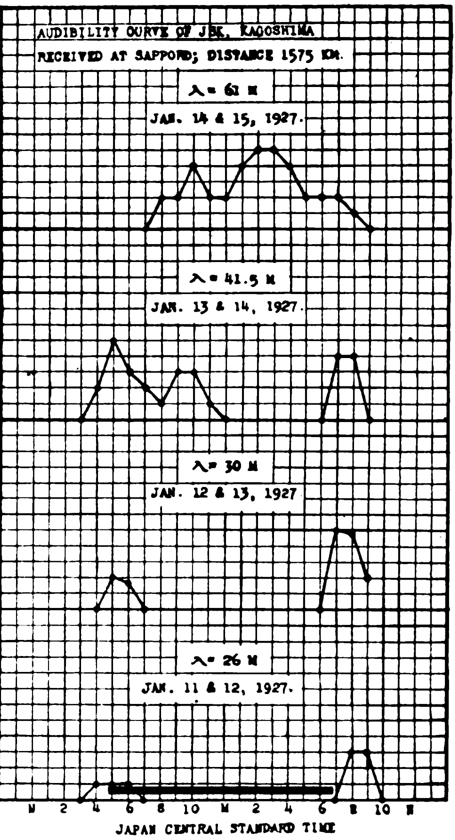


FIG. 1 - H



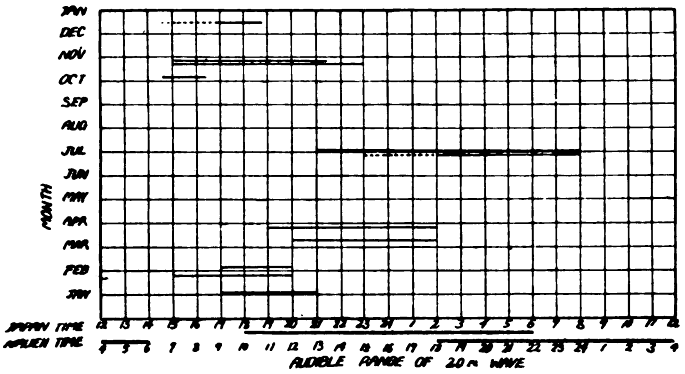
Seasonal Variation in Signal Strengths of the 20 meter Wave from Nauen in Japan,

by T. NAKAGAMI and T. ONO,

Direction General of Telegraph and Telephone Engineering, Ministry of Communications, Tokyo (Japan).

We made a series of the receiving tests of the 20 meter waves from Nauen at Iwatsuki Receiving Station near Tokyo for more than one year, and got the result which is summarized in the annexed figure. The hours during which Nauen signals were readable are shown for several seasons, in which we tried to receive the Nauen 20 meter wave for 24 hours.

In summer, there are about 11 hours of signal readability when the path from Nauen to Japan supposed to lie on the great circle is night-time, but in winter, they are reduced to only a few hours, shifting towards the time when the great circle passing through Nauen to Japan is daylight time. The great circle between Japan and Germany runs nearly tangential to the arctic circle on its middle part, so that the night-time in summer is not completely dark and the day-time in winter is not completely broad daylight, both resembling the condition of twilight. On this account the degree of ionization of the upper atmosphere is nearly the same in winter day-time and summer night-time; thus the conditions of the propagation of signals seem to be controlled by nearly the same factors.



* * *

The relation between radio reception, sunspot position and area,

by GREENLEAF W. PICKARD,

Wireless Specialty Apparatus C°, Boston (Mass., U. S. A.)

As a matter of years or even months, the relation between radio reception and solar activity is now quite definitely known (1). An increase of solar disturbance, as indicated by an increase in the number of sunspots, solar constant or ultraviolet radiation, is accompanied by an improvement in day reception and a lowering of night reception. By taking periodic daily averages for a number of solar rotations certain general day to day relations can be found; for example, the meridian transit of a sunspot group is usually accompanied by a depression of night reception and (with the exception of 1926 and the early part of 1927) a slight increase of day field (2).

Night reception in that portion of the broadcast band between 750 and 1,500 kilocycles and over East-West transmission paths shows the highest relation to measures of solar activity. But even with this most sensitive type of radio transmission, if intervals of less than a month are taken the degree of correlation rapidly decreases Comparing night reception at Newton Centre, Massachusetts, from stations WBBM and WGN at Chicago, with Wolfer Provisional Sunspot Numbers over the interval January, 1926 to September, 1927, the following correlations are found :

INTERVAL	CORRELATION	r/e
Three months . .	— 0,92 ± 0,038	24,0
Two months . . .	— 0,75 ± 0,093	8,1
One month . . .	— 0,54 ± 0,10	5,4
Fifteen days . . .	— 0,45 ± 0,084	5,4
Seven days . . .	— 0,30 ± 0,06	5

When a day to day comparison of reception and Wolfer sunspot numbers is attempted, a very low correlation is found. If recognition is taken of the distance of the sunspots from the

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(1) The Correlation of Radio Reception with Solar Activity and Terrestrial Magnetism. (*Proceedings of the Institute of Radio Engineers,* vol. 15, n° 2; February 1927.)

(2) The Correlation of Radio Reception with Solar Activity and Terrestrial Magnetism. *II.* (*Bulletin National Research Council,* n° 61, July 1927, *Proceedings of the Institute of Radio Engineers,* vol. 15, n° 9, September 1927.)

Sun's center, by multiplying their area by (1 — ρ), where ρ is the distance from the center of the solar disc, a somewhat larger correlation coefficient results. A further improvement results when only spots within a few degrees of the central meridian are taken. But even when position as well as area is considered, the connection between individual sunspot groups and reception is not sufficient to show that we are dealing with cause and effect.

As a working hypothesis, I have assumed that there are definite solar areas which are responsible for reception disturbances, and which usually persist for a number of solar rotations. In general these active areas are also areas of sunspot formation, but they are effective in producing reception disturbances even when they contain no spots. Large sunspot groups may also occur entirely outside these active areas, in which event the earthward presentation of such spots is less likely to be accompanied by changes in reception.

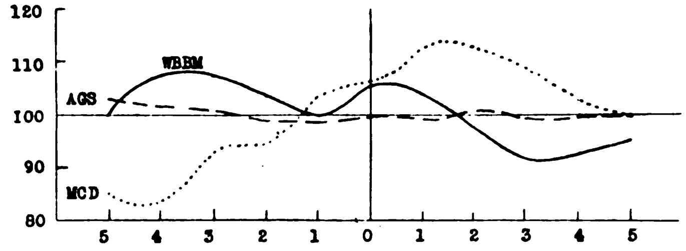

Fig. 1. — Reception and magnetism with maxima of 4 or more spots in central 13.3° band. 88 cases, Februari 17, 1926 to May 21, 1927.

But as the active areas persist for a number of solar rotations (sometimes over a year) and are the most likely places for sunspot formations, we may still use sunspot area and position to derive general relations despite their inadaquacy in the individual case. It is the object of this paper to show that the central passage of sunspots does not exactly coincide with the associated reception disturbances, and that the interval between the transit of the sunspots and the reception change varies both with the area of the sunspot group and with the particular period taken for investigation.

In the first seven figures night reception, day reception and terrestrial magnetism are compared with the central passage of sunspot maxima. The night reception is taken from my measurements at Newton Centre, Massachusetts, and Seabrook Beach, New Hampshire, of station WBBM at Chicago, the day reception is at Washington from AGS at Nauen, Germany, while the magnetic measure used is the Magnetic Character of Day Number given by the Observatory at Cheltenham, Maryland. The sunspots were counted in a central band 13,3° wide, which is one day's travel in solar rotation.

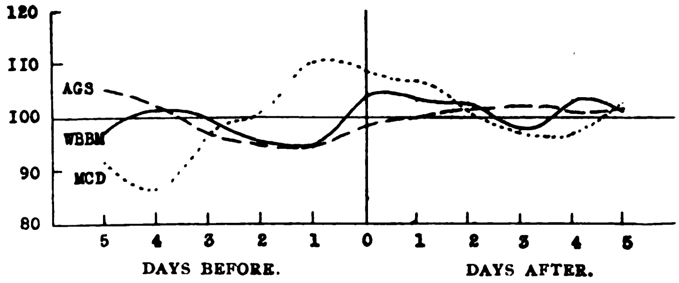

Fig. 2. — Reception and magnetism with maxima of 4 to 10 spots in central 13.3° band, 62 cases, February 17, 1926 to May 21, 1927.

In figure 1 is shown the relation between day and night reception, terrestrial magnetism and sunspot maxima of four or more spots, over the period February 17, 1927, to May 21, 1927. The ordinates represent percentage variation of the elements, and the graph covers an interval of eleven days. Night reception, shown in full-line, reaches a minimum about three days after the central passage of the spots, day reception an ill-defined minimum one day before, while magnetism, shown in dotted line, shows a maximum of disturbance between two and three days after.

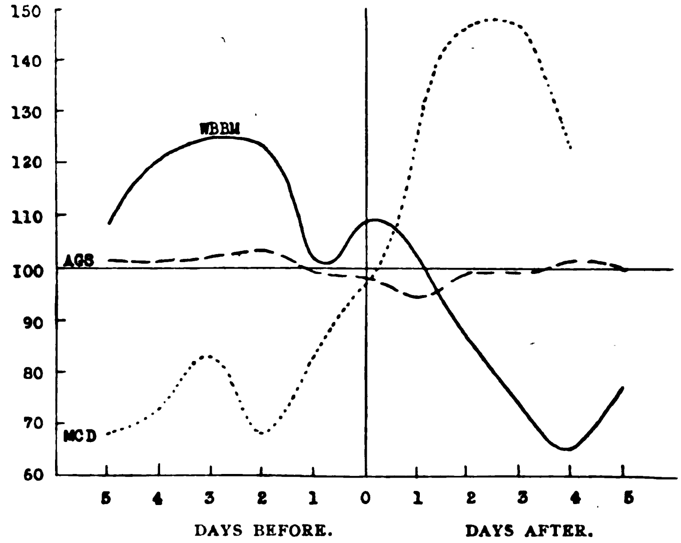

Fig. 3. — Reception and magnetism with maxima of 12 or more spots in central 13.3° band. 26 cases, May 13, 1926 to May 12, 1927.

A comparison of reception and magnetism over the same period, but with sunspot maxima limited to four to ten spots is shown in figure 2. Now both night and day reception show minima one or two days before, with a maximum of magnetic disturbance one day before.

In figure 3 only the larger sunspot groups are taken, with spot numbers of twelve or more in the central band. The amplitude of the night reception and magnetic disturbance has now increased, with minimum and maximum values, respectively, four and three days after the passage of the spots, while day reception shows a slight depression one day after.

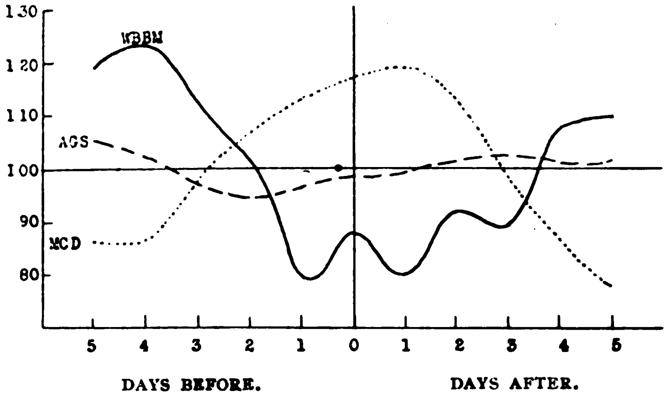

Fig. 4. — Reception and magnetism with maxima of 4 to 10 spots in central 13.3° band. 26 cases, February 17, 1926 to October 4, 1926.

It is evident from these figures that the interval between sunspot transit and reception depression is related to sunspot area, much as if the smaller spot groups were on the Western, and the larger spots on the Eastern boundary of the active areas. But there is another factor to be considered, namely the period covered by the observations. In the preceeding figures this has been approximately fifteen months; now this interval will be broken into two nearly equal parts. In figure 4 the interval is from February 17, 1926 to October 4, 1926, with sunspot maxima of four to ten. Night reception shows a depression centering one day after, magnetism a maximum one day after, and day reception a minimum two days before.

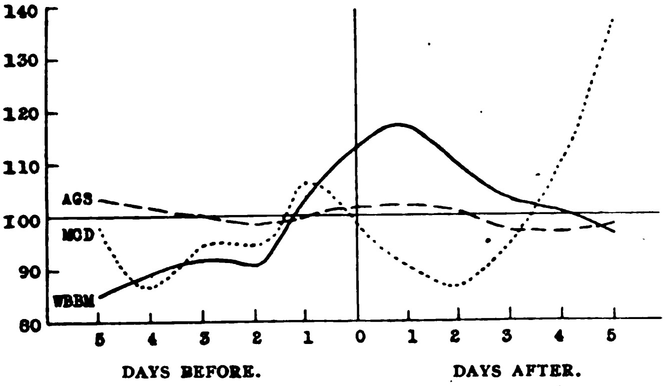

Fig. 5. — Reception and magnetism with maxima of 4 to 10 spots in central 13.3° band. 36 cases, October 8, 1926 to May 21, 1927.

In figure 5 the period is October 8, 1926 to May 21, 1927, with sunspot maxima of four to ten. Although at first sight this figure is the inverse of the preceeding one, the night reception maximum one day after the passage of the spots is not related to this particular transit, but merely represents reception recovery from some preceeding disturbance; actually what has happened is merely a considerable displacement in time. The inverse relation of magnetism and night reception is here the best guide to the true position of the reception minimum, which is more than five days after the spot transit. Apparently the smaller sunspot groups were quite near the center of the active areas during the first seven months, but in the second period they moved East by at least 65°.

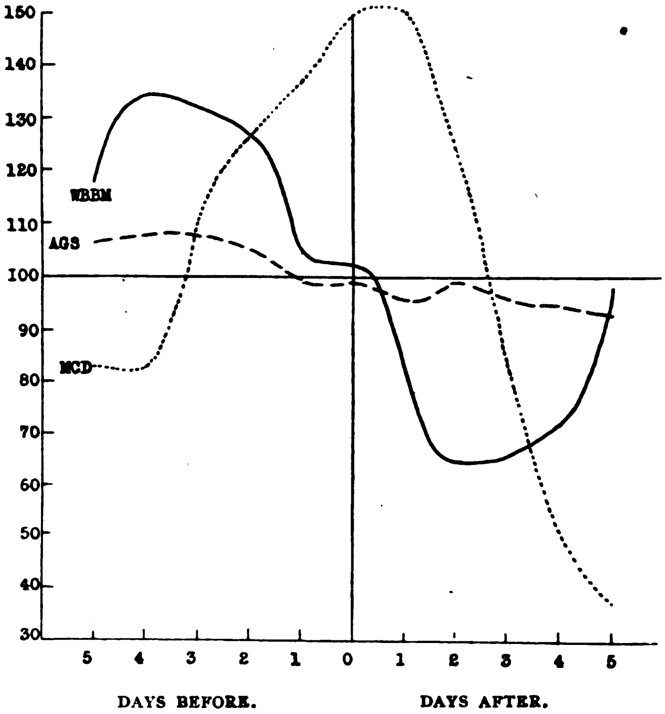

Fig. 6. — Reception and magnetism with maxima of 12 or more spots in central 13.3° band. 8 cases, May 13, 1926 to September 19, 1926.

The larger sunspot groups shows a similar displacement, altho to a lesser degree. In figure 6 reception and magnetism from May 13, 1926 to September 19, 1926, are compared with sunspot maxima of twelve or more. Night reception shows a minimum two days after, and magnetism a maximum one day after. Figure 7 is also for sunspot maxima of twelve or more, for the period of October 11, 1926 to May 12, 1927, and here the reception and magnetic elements show a minimum and maximum values three and four days, respectively, after the transit of the spots; a displacement of about two days to the right.

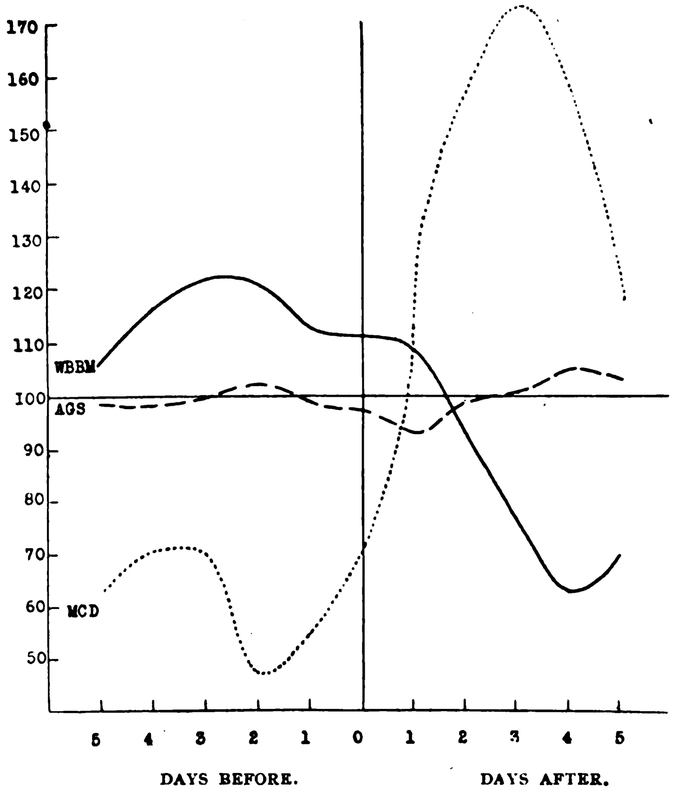

FIG. 7. — Reception and magnetism with maxima of 12 or more spots in central 13.3° band. 18 cases, October 11, 1926 to May 12, 1927.

It is aparent from the preceeding figures that the relation of reception to magnetism is much more intimate than its connection with sunspots. In figure 8 the magnetic storm is taken as the event, instead of sunspot transit. Within the nineteen months from January, 1926 to August, 1927, there were fourteen magnetic storms recorded by Cheltenham, and the depression of night reception accompanying these storms is very striking. Day reception shows an inverse effect, an increase of field accompanying and following the storm. The night reception maximum three days before is not in anticipation of the coming storm; it merely represents the recovery of reception from the depression associated with a preceeding magnetic disturbance.

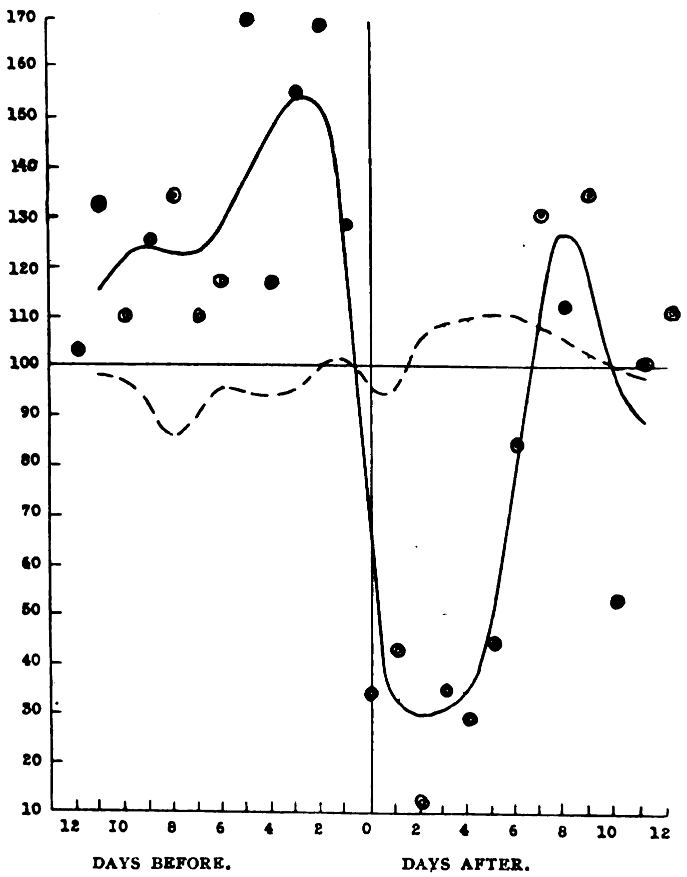

FIG. 8. — Reception from WBBM and WGN with magnetic storms observed at Cheltenham. 14 cases, January 26, 1926 to August 19, 1927. — AGS day reception in broken line.

Altho the most marked reception disturbances accompany magnetic storms, even a moderately disturbed day has its associated reception depression. In figure 9, which covers the period January 24 to June 12, 1927, all

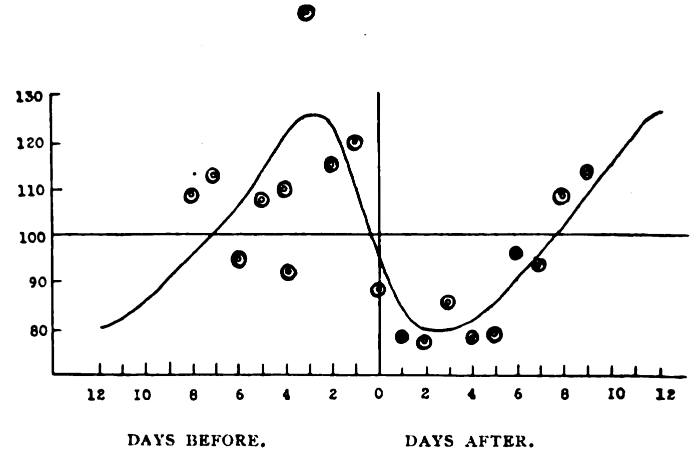

FIG. 9. — Mean reception from WBBM and WJAX at Washington and Newton Centre with maxima of magnetic disturbance at Cheltenham. 36 cases, January 24 to June 12, 1927.

magnetically disturbed days are taken, that is, all days with character number of one or two. The night reception data are here an arithmetic average of WBBM at Washington and Newton Centre, and WJAX of Jacksonville, Florida, at Washington. Over the first half of 1927 magnetic disturbances came at intervals of approximately fifteen days, so the reception maximum three days before represents the recovery of reception from the depression associated with a preceeding magnetic disturbance, and the curve has a period of fifteen days.

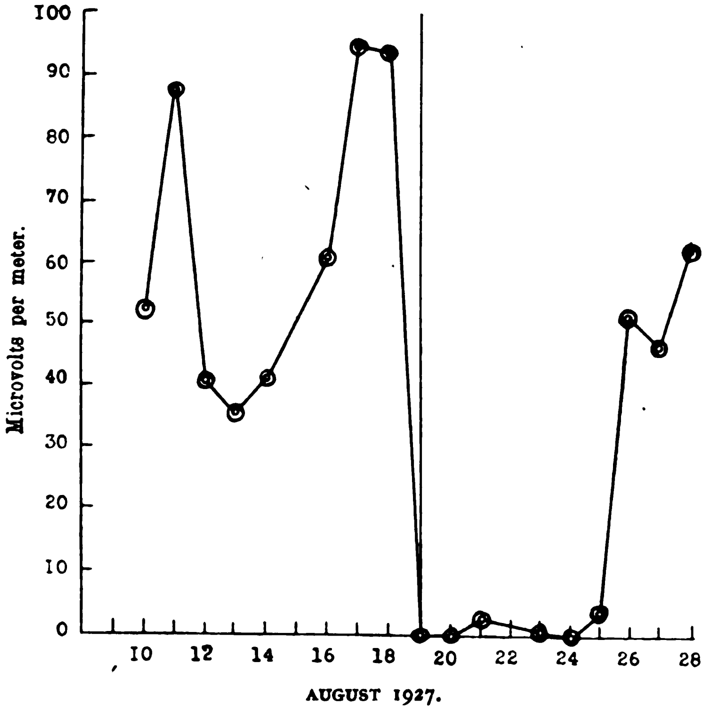

Fig. 10. — Night reception from WGN, Chicago, at Seabrook Beach, N. H., and the magnetic storm of August 19 and 20, 1927.

On the 19th and 20th of August, 1927, there was a magnetic storm of considerable intensity, with displays of Northern lights on both evenings, visible thruout New England. In figure 10 I have shown the reception depression associated with this storm, in which the field from WGN remained at a low value for a week.

Night reception over any extended period is largely a series of abrupt depressions followed by relatively slow recoveries. The recovery, at least during a sunspot maximum, is rarely completed before the next depression occurs, so that the mean field for, say, a month, is largely determined by the interval between these abrupt depressions. If this interval is short, for exemple a week, the mean field will be low; if two or three quiescent weeks intervene the mean field will be high.

These depressions quite definitely accompany disturbances of terrestrial magnetism, and less definitely the central passage of sunspot groups, but in neither case are we warranted in assuming that the connection is one of cause and effect. However, the relation of reception to terrestrial magnetism is so definite it is difficult to escape the conclusion that disturbances of these two elements arise from a common and nearby cause; an electrical change in our atmosphere. Any inexactness in this relation might be explained on the assumption that magnetic disturbances require an electrical movement, whereas reception is dependent upon the degree and disposition of ionisation.

* * *

Apparent night variations with crossed coil radio beacons,

by HARADEN PRATT,
Radio Engineer,
Bureau of Standards, Washington D. C. (U. S. A.)

It early became apparent that the employment of coil antennas on airplanes for determining the directions or bearings of radio stations was beset with difficulties. The coils were limited in size and considerable amplification was needed to secure a signal of suitable strength. Airplane engine ignition interferences in the radio receiving system prevented the use of very much amplification and so the distance range was limited. Further, the high level of noise present on aircraft prevented a close observation of the minimum signal sector during rotation of the coil, thereby by impairing the accuracy of that method as applied to aeronautical navigation.

Various means for the taking of radio station bearings from airplanes were attempted without realizing a practical solution of this problem and it was not until the crossed coil radio beacon was proposed that those interested in the art became encouraged to expect the evolution of a simple and workable system to guide aircraft.

The crossed coil beacon idea was investigated by the Bureau of Standards several years ago, since which time its development has been rapid, and there are now several of them available for service in the eastern part of the United States.

Essentially, this beacon comprises two coil antennas disposed in two vertical planes fixed at an angle with each other. This two coil system is free to be rotated about a vertical axis. When the coils are similarly excited at radio frequency, signals of equal intensity from each will be heard on a receiving set when located along any one of the four vertical planes bisecting the angles between the planes of the coils. At other points the signal intensities from each coil will be different. This marking off in space of a vertical equisignal plane constitutes the directive feature of the crossed coil type of beacon, and this equisignal zone is frequently referred to as the course set down by it.

In its practical application and for convenience in construction, the beacon used in this country employs a radiating system of two large fixed single-turn loops. A suitable goniometer interposed between these loops and the power source permits by its rotation, the rotation in space of the equisignal zones. A mechanical device automatically transmits the letter A on one coil and the letter N on the other. These are so interlocked that a continuous long dash is heard along the equisignal zone. The width of this zone where the dash only is heard depends largely upon the acuteness of the observer's attention, and may vary between limits, for example, from 1 1/2 to 3 degrees.

For the guidance of aircraft the crossed coil beacon possesses several obvious advantages.

1. There is no zone of minimum or maximum signal strength to be observed.

2. Location of the course or beam is secured by an automatic comparison of two signals.

3. Regardless of the position of the aircraft within a wide angle when off the course, this beacon furnishes a definite signal enabling the craft to locate, and return to its proper course. This characteristic permits temporary detours to be made during flight around stormy areas or obstructions, a very important and valuable feature.

4. The aircraft uses an ordinary receiving set with the usual trailing wire antenna permitting signals to be received under the most favorable conditions as regards minimum sensitivity of airplane receiving set to local noise and disturbances.

5. An aircraft may be guided along a set and invariable airway regardless of wind drift.

These advantages had much to do with the selection of this type of beacon for application to our national airway system, particularly those over which schedule mail airplanes operate.

To secure information of a practical nature, receiving equipment was recently installed on a mail airplane operating between the airports of Cleveland and New York, over an airway approximately 380 miles long. Two directive beacons were available, one at the New York terminal and the other at a point 170 miles west at Bellefonte, Pa. The frequency used was 290 kc. The radiating loops were of a triangular shape 300 feet long and 80 feet high. The current in each loop was 8 amperes. This route crosses the Alleghany mountain ranges which occupy nearly all of that region and is a particulary favorable one for this experimental flying both because of the rough topography and the prevalent foggy and cloudy weather.

The accuracy of the directive beacon as a guide had already been established as of a high order, through considerable use in the past, but upon examination of the situation it was learned that all previous experience with it had been confined to daylight flying. Its operation at night had been untried. Flights over the airway mentioned were therefore undertaken last summer and results inconsistent with those secured by day were immediately observed. During the first flight it seemed impossible to keep the airplane on a course corresponding to the interlocking dash signal. No sooner was this signal received when it would change to the letter A or letter N. No amount of manipulation of the airplane would improve the situation. The dash signal would come and go at intervals of a few minutes. Its soon became apparent that at this distance which was about ninety miles, no accurate fixed course existed but that the equisignal zone was moving about in an indefinite way.

This disconcerting effect indicated that a study of the phenomenon must be made, and several night flights up to distances of 175 miles from the beacon were undertaken. In every case the shifting of the zone or course was noticed. The general results secured from five flights made at an average altitude of 2,000 feet may be stated as follows :

1. Within 25 miles of the beacon the shifting was not of a serious nature.
2. At 50 miles the shifting became pronounced but due to the zone being stationary in its proper position for possibly 75°/₀ of the time, the beacon could still be depended upon.
3. At a distance of 100 miles the shifting became very pronounced and persisted for more than 50 °/₀ of the time.
4. At 125 miles the beacon was of no further value as a guide.
5. The shifting of the zone was gradual so that at first one would be inclined to think it due to the movement of the airplane.
6. It appeared that the topography of the country between the beacon and the airplane exerted a considerable influence on the extent of the variation.
7. Exceptional variations in shift over as much as 100 degrees in azimuth were noted, but in general the change was confined to within possibly 25 degrees.
8. Beyond 15 miles the fading of the general level of signal received was very severe during flight over mountains. Several variables being involved, no conclusions have been reached as to the relative contribution of each factor, except that more steady signals were observed at fixed points on the ground than in the air, at similar distances from the beacon.

A few observations of the Bellefonte beacon at night have been made on the ground at Washington. While present, the shifting phenomenon was less pronounced than that observed in the air. On a night flight from Harrisburg to Washington no shifting of the zone was noticed, using signals from a beacon at College Park, Md. As there are no marked mountain ranges near College Park, these observations would indicate that topographical features have an important bearing on the matter of these variations.

To shed further light on the question, two sets of night-time measurements on the Bellefonte beacon have recently been made, one at a point 22 miles and another 32 miles distant, both locations being in mountainous territory. Records obtained with a graphic field intensity recorder were made of signals using both a vertical antenna and a coil antenna placed in a vertical plane extending towards the beacon. Ratios of the variability to average field intensity were observed to be,

at 22 miles with	coil antenna . . .	0.25
»	vertical antenna. .	0.00
at 32 miles with	coil antenna . . .	0.44
»	vertical antenna. .	0.07

Ratios of the variability to the maximum field intensity were observed to be,

at 22 miles with	coil antenna . . .	0.43
»	vertical antenna. .	0.05
at 32 miles with	coil antenna . . .	0.56
»	vertical antenna. .	0.1

Rotating the coil antenna around its vertical axis so as to receive minimum signal showed a variation in the direction of the arriving field as large as 30° over a ten minute interval.

In closing I might mention that although the equisignal zone ordinarily remains stationary in its correct position during daylight hours, sudden shifts of a few moments duration have been noticed in the mountainous country, particularly when flying down river valleys at altitudes of 1,000 to 1,500 feet.

It is hoped that this brief outline of these few preliminary observations made by the staff of the Bureau of Standards, will serve to focus attention on the performance of this type of radio beacon so that its limitations as a guide for flights at night may be studied and practical information secured whereby these performance characteristics and the conditions influencing them may become better understood.

October 12, 1927.

* * *

A Radio Frequency Oscillator for Receiver Investigations,

by GEORGE RODWIN and THEODORE A. SMITH,
Technical and Test Department, Radio Corporation of America
(New York, N. Y., U. S. A.)

A modulated radio frequency oscillator forms a piece of apparatus which is extremely useful in an experimental laboratory. By incorporating a number of special features, such an oscillator can be made very flexible and its uses varied.

The equipement to be described was originally built in connection with work done in determining certain radio receiver characteristics (1). The oscillator has also been used for providing known fields in the measurement of field intensities, determining coil resistance and inductance, lining up radio circuits, and for other general laboratory purposes.

The design was such as to satisfy as far as possible the following requirements :

1. The oscillator output should be widely variable without any appreciable change in frequency.
2. A means for reading the output should be provided.
3. The frequency should be variable over a given range (such as the broadcast band) and the calibration should be maintained.
4. At any frequency setting, it should be possible to vary the frequency in small continuous steps to either side of the setting with a fair degree of accuracy.
5. Modulation should be obtainable up to at least $50\,^{\circ}/_{0}$ with means for indicating continuously the percentage of modulation.
6. The stray field from the apparatus should be low compared to the field produced by the known radiator used.
7. Mechanical details should be such as to enable the operator to take data quickly and easily.

The apparatus to be described meets these requirements satisfactorily. Many details have been thoroughly developed and retained in this device, with the result that the oscillator may appear rather large and bulky. However, when it is considered to what varied use it may be put, its large size is justified.

ELECTRICAL CONSTRUCTION.

The complete apparatus consists of a modulated oscillator-power amplifier arrangement, with an output and measuring circuit. A schematic diagram appears in Fig. 1.

General Circuits. — It was found that the master-oscillator-power amplifier method for the generation of radio frequency currents had several advantages over the use of a simple oscillator. The oscillator employs a UX — 201A tube in an ordinary Hartley circuit. A grid condenser of 500 micro-microfarads with a grid leak of 20,000 ohms gives sufficient constancy of frequency for small variations in filament and plate voltage, without greatly reducing the radio frequency output. For the broadcast band, an inductance of 82 microhenries with a variable condenser of 1,000 micro-microfarads maximum capacity forms the tuned circuit. The variable condenser, which is of the straight line frequency type, is purposely made large, so that only the really straight portion of its frequency calibration is normally used, while still maintaining a three-to-one range in frequency. In order to minimize the effect of tube capacity in different tubes on the frequency calibration, a small fixed condenser of about 60 micro-microfarads capacitance is placed in parallel with the main tuning condenser. This addition was found to improve the frequency-setting relation of the main control. Figure 2 shows this relation for the apparatus constructed.

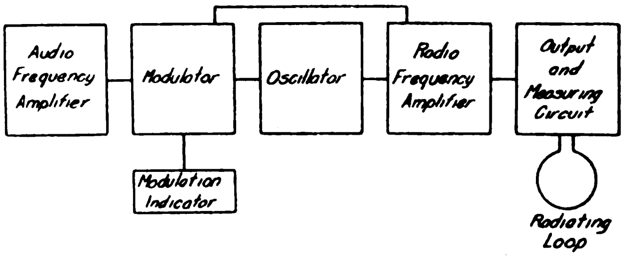
Audio Frequency Amplifier
Modulator
Oscillator
Radio Frequency Amplifier
Output and Measuring Circuit
Modulation Indicator
Radiating Loop

FIG. 1. — Schematic Diagram of Modulated Oscillator-Amplifier.

A mechanical arrangement is employed for varying the frequency in small steps. This device is explained in detail below. Frequencies in steps of 1,000 cycles up to 8,000 cycles to either side of a given frequency can be obtained. The calibration of this adjustment was carried out as follows :

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(1) *Proceedings of the Institute of Radio Engineers*, vol. XV, n° 5, May 1927, p. 389.

With the vernier control at its zero position, a zero beat is produced in a radio receiver with a separate external oscillator, the frequency of which is known to be constant over the period of the calibration. When the vernier is moved off its zero position, a beat note will occur, which is compared with a calibrated audio frequency source, adjusting the pitch of the beat-note so that it is equal in frequency to the known audio frequency. This operation was repeated for a number of frequencies up to 8,000 cycles to either side of the vernier zero position.

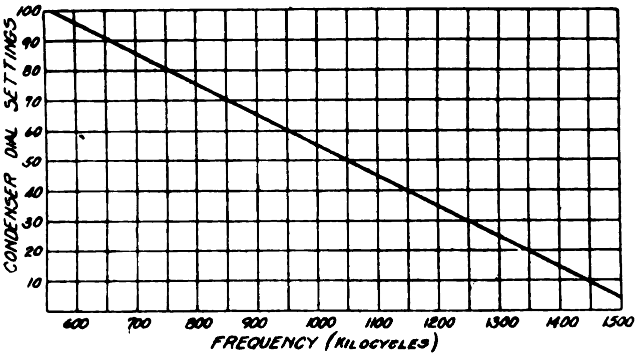

FIG. 7. — Apparatus Frequency. — Setting Relation.

Since the vernier control is constructed so as to move the tuning condenser a constant amount, in angular motion, for a given rotation of the vernier, and since the variable tuning condenser has a straight line frequency characteristic, the calibration of the vernier will hold for all radio frequencies. This was checked by repeating the above beat-note comparisons for various condenser positions and the vernier calibration was found to be practically constant over the whole frequency range.

The radio frequency power amplifier has its grid circuit coupled to the oscillator circuit by means of an untuned inductance. Two UX — 112 tubes are employed in parallel and these are neutralized. The power amplifier is operated as a « proper amplifier » and its grid excitation is such as to obtain maximum output under these conditions. The amplifier plate circuit is tuned by a condenser placed on the main tuning condenser shaft.

The output circuit is coupled to the amplifier plate coil, its coupling being continuously variable for output control. It was found desirable to have quite a large range of output — at least 5,000 to 1 in current. The combination of a radio frequency current transformer, thermo-couple milliammeter and switching arrangement has been found satisfactory for providing and metering such a widely varying output.

Current Transformer for Provision of Various Output Currents. — The current transformer for radio frequencies (1), in the form employed in this apparatus, has an iron core of 10 mil (0.0254 centimeters) toroidal silicon steel laminations, 9/16 inch (1.43 centimeters) thick, 2 inches (5.08 centimeters) outside diameter, and 1 inch (2.54 centimeters) inside diameter. The core is covered with insulating oiled silk and one winding of 100 turns is evenly spaced over this core. The other winding of either 1 or 10 turns is looped through the hole in the toroid. Wood blocks keep the windings well spaced from one another so as to reduce capacity effects between the windings and maintain the current ratio. The construction is shown in Fig. 3.

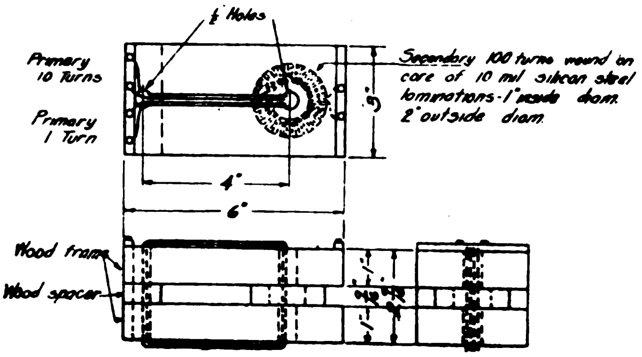
¼ Holes
Primary 10 Turns
Primary 1 Turn
Secondary 100 turns wound on core of 10 mil silicon steel laminations-1" inside diam. 2" outside diam.
3"
4"
6"
Wood frame
Wood spacer
1"
1"

FIG. 3. — Current Transformer for the Measurement of Output Currents.

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(1) D. W. DYE, *Measurement of Alternating Electric Currents of High Frequency.* (Proceedings of Royal Society [of Great Britain] A-1914, vol. XC, p. 621.)

Bureau of Standards Circular 74, p. 153.

D. W. DYE, *Current Transformer Methods of Producing Small Voltages and Currents at Radio Frequencies for Calibrating Purposes.* (Journal Institution of Electrical Engineers, London, June 1925, vol. LXIII, p. 597.)

It can be shown that the current ratio for such a transformer is given by an expression of the form

$$\frac{I_1}{I_2} = \frac{n_2}{n_1}\left(1 + \frac{\alpha R_2}{\omega L_2}\right)$$

where I_1 and n_1 are the primary current and turns number respectively.

I_2 and n_2 are the secondary current and turns number respectively.

R_2 and L_2 are the secondary resistance and inductance respectively.

α is a coefficient depending on the iron losses, having a value usually less than 1.

When $\frac{\alpha R_2}{\omega L_2}$ is small compared to 1, this expression reduces to

$$\frac{I_1}{I_2} = \frac{n_2}{n_1}$$

The secondary circuit contains the ammeter resistance and, for accuracy of transformation this must be made low compared to the inductive reactance of the transformer secondary. For the transformer of the dimensions given used at frequencies in the broadcast spectrum, a 43 ohm thermo-milliammeter (0-8 milliamperes) has been found satisfactory. The ratio was checked by measuring the currents in both windings and an accuracy of better than 5 °/₀ was found throughout the range of currents and frequencies required.

Fig. 4 shows the complete wiring diagram of the apparatus and from it may be seen the method of using the current transformer. A six-pole, five point switch allows the meter to be used in either the primary or secondary of the current transformer so that current ratios of 1-100, 1-10, 1-1, 10-1, or 100-1 may be obtained between the meter circuit and the load or radiating loop circuit. The capacity between various switch parts has been kept low. In addition, the effects due to any undesirable capacities are minimized by the use of low impedance load and metering circuits.

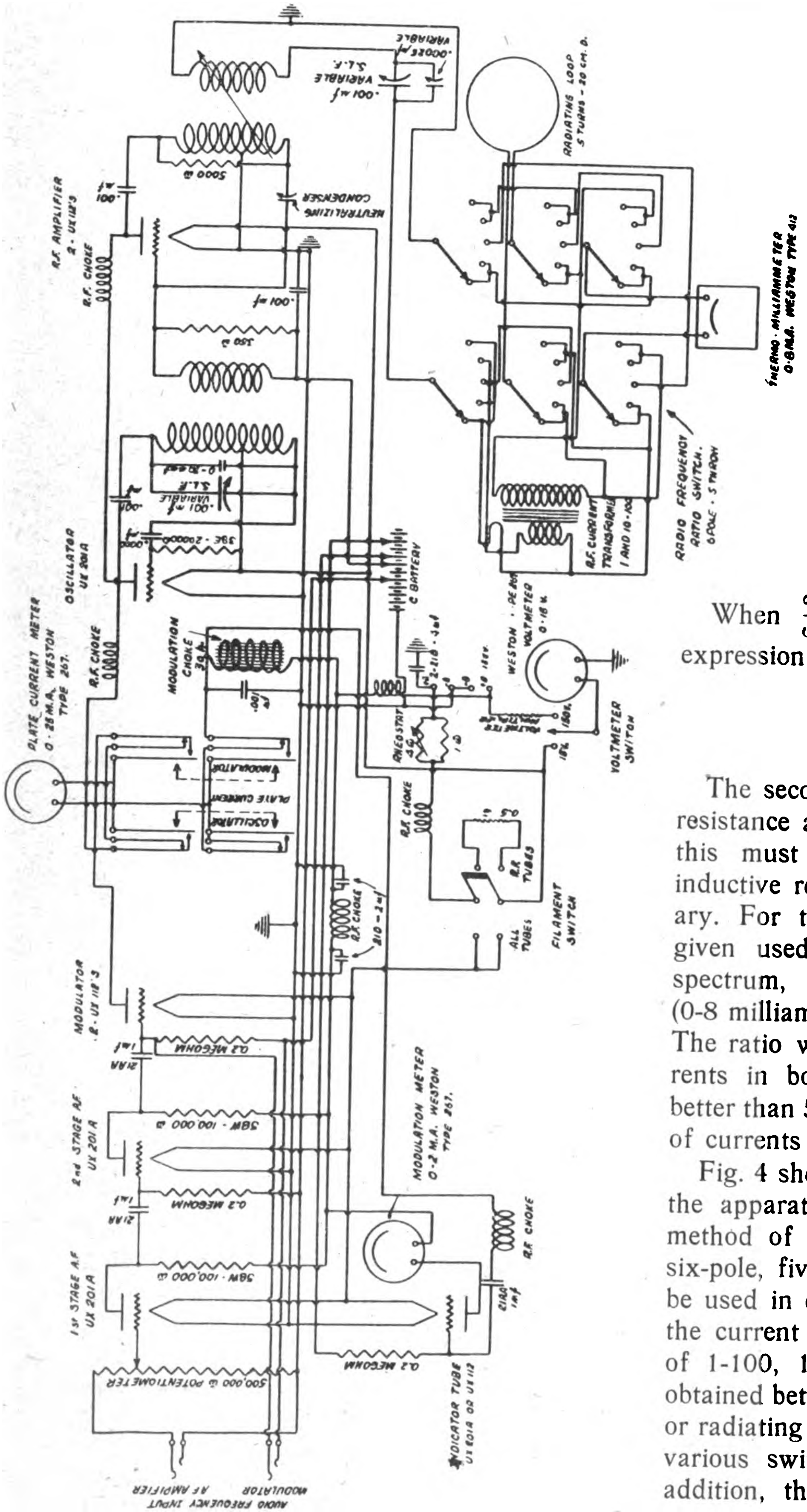


FIG. 4. — Complete Circuit Diagram of the Apparatus.

Provision of Known Fields. — The radiating loop with a known current in it may be used to induce an easily calculated voltage in a second loop having a known mutual inductance between loops. Known field intensities in a plane x centimeters from the loop and parallel to the plane of the loop can be calculated from the field H which is

$$H = \frac{2\pi a^2 in}{10} \times \frac{1}{(x^2 + a^2)^{3/2}} \text{ gausses}$$

The field intensity in $\frac{\text{volts}}{\text{cm}} = 300$ H.

Thus,

$$E = 18850 \frac{a^2\, in}{(x^2 + a^2)^{3/2}} \times 10^6 \text{ microvolts per meter}$$

where a is the radius of the loop in centimeters.

i is the loop current in amperes.

n is the number of turns on the loop.

If the plane in which it is desired to know E is at an angle to the plane of the loop, the field intensity may be calculated from the above expression, introducing a factor of the cosine of the angle between planes. Field intensities ranging from ten to one million microvolts per meter are readily obtained in this manner.

Modulation. — The conventional plate circuit choke coil method is used for modulation, two UX — 112 tubes controlling both master-oscillator and power amplifier. This system has been found satisfactory for the purpose. Fairly high degrees of modulation are obtainable. The relation between input voltage and percentage modulation has been found linear up to 70 °/₀. For measuring the percentage of modulation, the ordinary method of measuring the audio frequency voltage across the modulation reactor and comparing this value with the direct current plate voltage of the oscillator and modulator will not apply. This is due to the fact that both the oscillator and radio frequency amplifier are being modulated. The cathode ray oscillograph has been used for modulation-percentage determination. One set of the oscillograph plates is excited from the voltage induced in a pick-up coil coupled to the radiating loop. The oscillator is modulated from an audio frequency source. The other set of oscillograph plates is supplied with voltage from the same audio source. In general, the resulting oscillograph figure is a trapezoid. The various forms it may take are shown in Fig. 5.

Using the symbols of Fig. 5, the modulation is given by $\frac{2x}{m} \times 100$ °/₀. But $m = \frac{a+b}{2}$ and $x = \frac{a-b}{4}$ therefore modulation $= \frac{a-b}{a+b} \times 100$ °/₀.

As an indicating device, a UX — 201A tube is employed with its normal plate current biased to practically zero and its grid excited from the audio voltage developed across the modulation reactor. The plate circuit of this tube contains a 0-2 milliampere ammeter the scale of which has been calibrated directly in modulation percentages using the oscillograph method described. A radio frequency choke and by-pass condenser prevent the radio frequency voltage from affecting the indicator tube reading. With the radio frequency amplifier tubes operating properly and the circuits equalized, the modulation indication is practically constant with varying radio frequency.

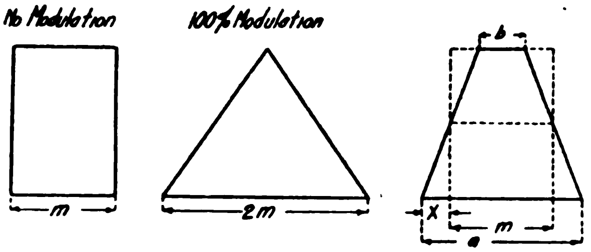


Fig. 5. — Cathode-Ray Oscillograph Figures used in Modulation Percentage Determination.

A two-stage resistance-coupled amplifier supplies sufficient voltage to the modulator grids. Its characteristic is practically flat over a wide range of audio frequencies.

Equalization of Output Current. — The radio frequency output current was found to vary considerably with frequency and a constant output was believed to be desirable. A means for correcting this fault to a considerable extent was devised. This consisted of placing suitable fixed resistances across both the radio frequency amplifier coupling coil and its output coil. The variation of output current in the radiating loop was thus made less than 15 °/₀ for a constant output coupling setting over the frequency range. These resistances were also found to lessen the effect of the tuned circuit on the audio characteristics.

Overall audio frequency characteristics from audio amplifier input to modulated radio frequency output are shown in Fig. 6. The data for these curves was taken by rectifying some of the voltage picked up with a biased detector tube and observing the audio frequency output. A slight effect of resonant circuit selection still remains, but this is not of any considerable magnitude and can be allowed for in exact measurements.

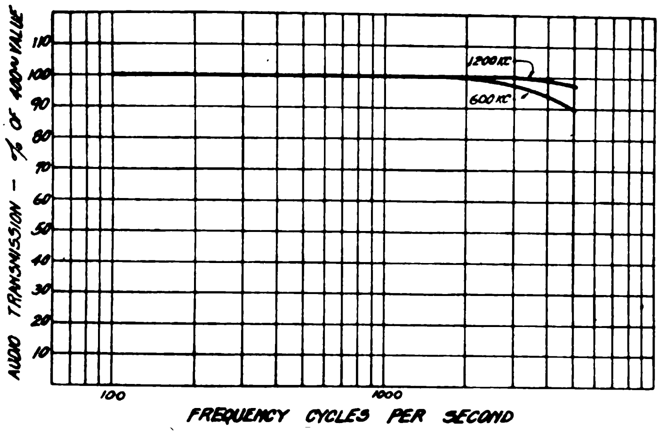


Fig. 6. — Overall Audio Frequency Characteristics of the Apparatus.

MECHANICAL CONSTRUCTION.

Tuning and Vernier Controls. — The oscillator and output tuning condensers are both mounted on the same shaft and are controlled from a single dial on the front panel. A friction cam arrangement has been found suitable for vernier adjustment. This consists of a lever and friction plate on the main shaft and a cam on a separate vernier shaft. The end of the lever arm bears on the cam and is held in position by a strong spring. Any movement of the vernier shaft will cause the lever to move either up or down a small amount and, since the friction plate is now bound to the main shaft, the main tuning condensers will move a small amount. The main tuning shaft can be moved without disturbing the vernier arrangement, since the friction plate will slip and the vernier lever arm will remain fixed due to the combined action of the spring and the cam rest. The criterion of whether such a system will operate is that the force required to move the friction plate over its bearing should be greater than the bearing friction in the tuning condensers. In practice, this is easily accomplished. The details may be seen in figures 7 and 8.

The whole apparatus is mounted in a double copper shielded box. The front panel and base board have been made removable as a unit for convenience. The various units, such as audio frequency amplifier, oscillator, radio frequency amplifier, and output circuit, are shielded from one another. The details may be seen in figures 9 and 10. The grid batteries are located in a separate compartment, but the filament battery of 6 volts and the plate battery of 135 volts are located outside the shielded box. Radio frequency filters in the battery leads prevent radiation from these.

The thermo-milliammeter for the measurement of output is placed externally near the apparatus, a twisted pair of leads of short length being used for connections.

In conclusion, we desire to mention that this design was carried out under the direction of Mr. Julius Weinberger, whose suggestions were very valuable in the development of the equipment.

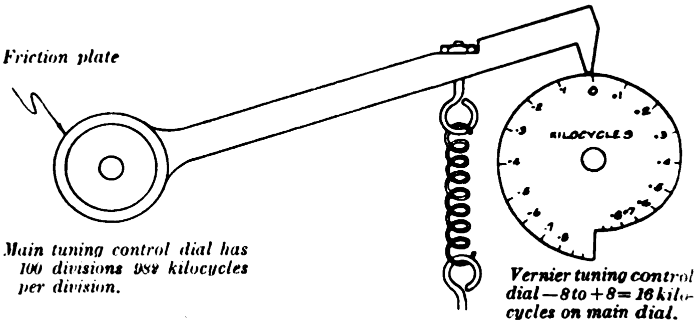

Friction plate
KILOCYCLES
0
Main tuning control dial has 100 divisions 988 kilocycles per division.
Vernier tuning control dial —8 to +8= 16 kilocycles on main dial.

Fig. 7. — Cam and Lever Used for Vernier adjustement.

SUMMARY.

A modulated radio frequency oscillator is described. This apparatus incorporates a means for obtaining radio frequency outputs of widely varying range, a metering system, a means for changing the generated frequency in small steps to either side of a given frequency, and a modulation and indicating system.

* * *

The effect of Retroaction on the Received signal strength (*),

by BALTH. VAN DER POL, D. Sc.
(Eindhoven-Holland)

The considerable increase in signal strength obtainable through the use of retroaction (feed back) is well known. It is also common knowledge that this increase in signal strength is considerably greater when originally the incoming signal is weak than when it is strong. It is the purpose of this paper to provide a non-linear theory of this effect of retroaction and the experimental verification thereof.

Suppose a triode system of one degree of freedom, as in Fig. 1 given, where L, C, r form the tuned circuit and the mutual induction M provides the retroaction.

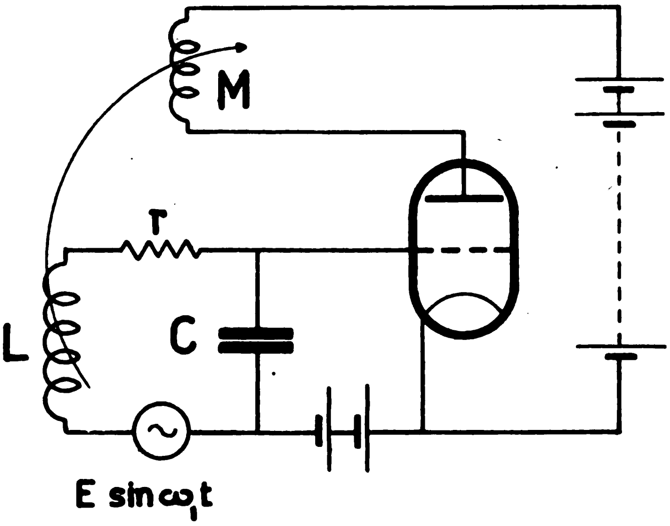


FIG. 1.

Let further an E. M. F. E $\sin \omega_1 t$, representing the « incoming signal » act on the oscillatory system. Neglecting the grid current and calling the current in the LCr circuit i, and the deviation of the anode current from its steady value i_a and the alternating grid P. D. v_g we have

$$L\frac{di}{dt} + ri + \frac{1}{C}\int i dt - M\frac{di_a}{dt} = E \sin \omega_1 t, \qquad (1)$$

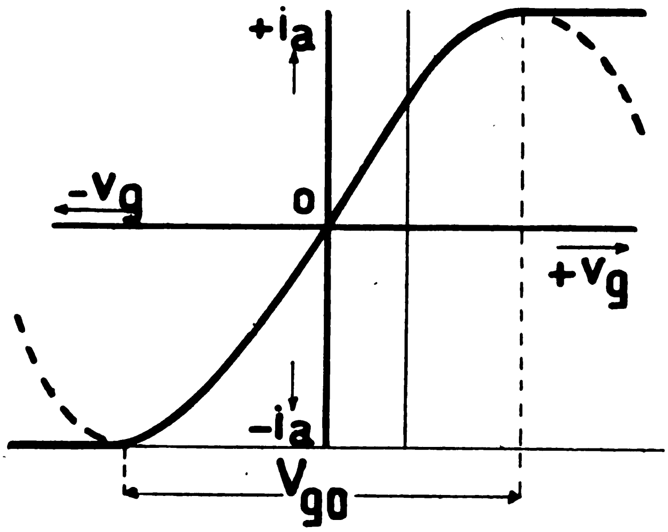
$$\frac{1}{C}\int i dt = v_g. \qquad (2)$$

In the « tuned grid » -circuit, the variations of anode potential are usually small compared with the variations of the grid potential, so that as a first approximation, the anode current variation i_a is a function of the grid potential variation only, i. e.

$$i_a = f(v_g). \qquad (3)$$

In order to avoid complexity we neglect the grid current and we therefore imagine a negative grid bias to be provided. Our system of coordinates in the i_a, v_g plane is therefore as shown in Fig. 2. This differs from the usual notation in so far as the zero point of the coordinate system is shifted towards the steady d. c. position round which the oscillations occur.

Equation (3), representing the curved anode current -grid potential characteristic of the triode, we approximate by the cubic :



$$i_a = S_1 v_g + S_2 v_g^2 - S_3 v_g^3$$

FIG. 2.

$$i_a = S_1 v_g + S_2 v_g^2 - S_3 v_g^3 \qquad (3a)$$

where S_1 is the usual « mutual conductance » for infinitesimal grid potential variations. S_2 and S_3 are further determined by the form of the characteristic. As the latter bends round both at the top and at the bottom we write in (3a) $- S_3 v_g^3$ in stead of $+ S_3 v_g^3$.

The elimination of i and i_a from (1), (2) and (3a) results in :

$$\left.\begin{aligned} \frac{d^2 v_g}{dt^2} + \left\{\left(\frac{r}{L} - \frac{MS_1}{LC}\right) - \frac{2MS_2}{LC} v_g + \frac{3MS_3}{LC} v_g^2\right\}\frac{dv_g}{dt} \\ + \omega_0^2 v_g = \omega_0^2 E \sin \omega_1 t. \end{aligned}\right\} \qquad (4)$$

(*) Paper read at the Meeting of the U. R. S. I. at Washington D. C., October 1927.

where

$$\omega_0^2 = \frac{1}{LC}.$$

Calling further

$$\frac{r}{L} - \frac{MS_1}{LC} = -\alpha,$$

$$\frac{MS_2}{LC} = \beta,$$

$$\frac{MS_3}{LC} = \gamma,$$

(4) becomes

$$\ddot{v}_g + (-\alpha - 2\beta v_g + 3\gamma v_g^2)\dot{v}_g + \omega_0^2 v_g = \omega_0^2 E \sin \omega_1 t, \quad (4a)$$

which is a non linear inhomogenous differential equation of the second order with non linear resistance terms.

The usual elementary approximation of a linear characteristic would make $\beta = \gamma = 0$ and for resonance (i. e. $\omega_0^2 = \omega_1^2$) and critical retroaction (i. e. $\alpha = 0$) the developing grid p. d. v_g would become infinite. In order to obtain a satisfactory theory of the response of a retroactive triode system to an impressed E. M. F. a non linear problem must therefore be solved.

The equation (4*a*) was fully considered in a former paper (*); from the results obtained there it follows that the steady state solution in the neighbourhood of resonance

$$(\,|\,\omega_0 - \omega_1\,|\, \lll \omega_1)$$

can be written :

$$v_g = b \sin(\omega_1 t + \varphi),$$

where the amplitude *b* of the resulting grid potential variation is given by :

$$b^2 \left\{ 4(\omega_0 - \omega_1)^2 + \left(\alpha - \frac{3}{4}\gamma b^2\right)^2 \right\} = \omega_0^2 E^2, \quad (5)$$

a cubic equation in b^2. It is further seen from (5) that the asymmetrical term in (4*a*) (with β) (which determines the detection) has, in the first approximation here considered, no influence on the resulting v_g. *Therefore as a first approximation detection has no effect on the h. f. grid potential difference developping under the influence of an incoming « signal ».*

Further, if (5) is compared with the usual linear case as represented by

$$b^2 \{ 4(\omega_0 - \omega_1)^2 + \alpha_0^2 \} = \omega_0^2 E^2$$

it follows that in the non-linear case $(\alpha - \frac{3}{4}\gamma b^2)$ is substituted for α_0, i. e., the system behaves as if for the resistance

$$r$$

a new resistance r' were substituted of a value given by

$$r' = r - \frac{M}{C}\left(S_1 - \frac{3}{4} b^2 S_3\right), \quad (6)$$

which therefore depends upon the amplitude *b* present already in the system (*).

When the retroaction is pushed so far that

$$\frac{MS_1}{C} > r, \quad (7)$$

it is seen from (6) that the first order differential resistance of the system becomes negative and therefore the system has the tendency to oscillate spontaneously. However, as was shown in the Phil. Mag. paper quoted above, the forced oscillations may suppress the development of the free oscillations which phenomena manifests itself through the presence of a « silent region » extending at both sides of resonance. As was shown by Prof. Appleton (**) the width of this silent region is determined by the amplitude of the incoming signal. For strong signals this width is given by

$$\frac{\omega_0 - \omega_1}{\omega_0} = \pm E . \sqrt{\frac{3\gamma}{\alpha}}. \quad (8)$$

It is of interest to investigate the resultant grid amplitude *b* if

a, the system is tuned exactly to resonance, i. e.

$$\omega_0 = \omega_1,$$

and **b**, it is brought on the verge of free oscillation, i. e. when

$$S_1 M = Cr. \quad (9)$$

(*) Phil. Mag., **3**, 65, 1927.

(*) This property of the non-linear system was first derived in 1920, see : Balth. Van der Pol, *Radio Review*, November, December 1920.

(**) E. V. Appleton, *Proc. Camb. Phil. Soc.*, **23**, 231, 1923.

For this case we at once obtain from (5)

$$\frac{3}{4}\gamma b^3 = \pm \omega_0 E, \tag{10}$$

which expression will now be considered in detail.

Firstly it follows from (10) that *the resulting grid amplitude is proportional to the cube root of the E. M. F. acting on the system.*

Further it is easy to assign an approximate value to γ directly from the triode characteristic.

Referring to (3*a*), (4*a*) and Fig. 2, and taking the symmetrical case for which $S_2 = 0$, it follows that a good approximation to S_3 can be found from the maximum and minimum value of the cubic (3*a*), for $i_a = i_{a\ \mathrm{max.}}$ when $v_g^2 = \frac{S_1}{3S_3}$.

Calling therefore the grid voltage change necessary to bring the anode current from zero to its saturation value the « grid space » and designing it by V_{g0} (see Fig. 2), we obtain

$$V_{g0}^2 = \frac{4S_1}{3S_3},$$

hence

$$\gamma = \frac{M}{LC}\,\frac{4S_1}{3V_{g0}^2}.$$

But, when the system has critical retroaction (9) obtains, i. e.

$$M = \frac{Cr}{S_1},$$

hence

$$\gamma = \frac{r}{L}\cdot\frac{4}{3V_{g0}^2}.$$

When we further call v_{g1} the grid voltage amplitude which would be obtained with no retroaction at all ($M = 0$) or (which is the same thing) with dimmed filament, we find from (5)

$$v_{g1}^2 = \frac{\omega_0^2 L^2}{r^2}\cdot E^2,$$

hence we obtain from (10) :

$$b^3 = v_{g1}\cdot V_{g0}^2$$

or

$$\boxed{b = \sqrt[3]{v_{g1}\cdot V_{g0}^2}} \tag{12}$$

reading in words :

The grid amplitude developping in resonance and with critical retroaction equals the cube root of the product of the grid amplitude which would be obtained with no retroaction at all, and the square of the « grid space » V_{g0}, as defined by Fig. 2.

(12) can further be written :

$$\frac{b}{v_{g1}} = \left(\frac{V_{g0}}{v_{g1}}\right)^{2/3} \tag{13}$$

which means that : *the amplification obtained through retroaction equals the two third power of the ratio of the « grid space »* V_{g0} *into the amplitude obtained with zero retroaction.* The much greater gain obtained through retroaction with small signals than with stronger ones is at once apparent by (13).

Some measurements provided a very satisfactory experimental verification of the theory outlined above.

The measurements were taken with relatively low frequency, thus avoiding obvious errors. That the results are however equally applicable to high frequency circuits follows at once from the following theorem :

If a model is made of a high frequency system consisting of linear inductances, linear capacities and non linear resistances (e. g. triodes) and if the values of all the inductances (self and mutual) and capacities in the model are made n *times these values in the original high frequency system, but if the resistances (linear and non-linear) in the model are made equal to the resistances in the original circuit, the currents and potentials occurring in this model will be equal in magnitude to the currents and potentials in the original high frequency system but, considered as a function of the time, they will vary* n *times slower* (*).

Therefore the natural periods of the model will be *n* times those of the original system, and the building up and decay of currents in the model will also occur *n* times slower.

This simple theorem at once follows from a

(*) Incidentally in this model system the stray capacities are reduced *n* times in magnitude. Therefore, in order to investigate the effect of a specified stray capacity in the original high frequency circuit it is only necessary to insert at its place in the model circuit a capacity *n* times the original stray capacity.

dimensional consideration of the coefficients such as

$$r, \quad \omega L, \quad \frac{1}{C\omega}, \quad M\omega,$$

occurring in the differential equations, because e. g.

$$L\omega = Ln \cdot \frac{\omega}{n}, \text{ etc.}$$

In fact, with a system having a natural frequency of 500 Hertz and with critically adjusted retroaction it often took a minute for the free oscillation of the triode system to reach its final value, hence it was not easy to decide, before the external E. M. F. was applied, whether the retroaction was exactly critical or not. Therefore an intermediate way was chosen and a model of a receiving set was made having a natural frequency of 15,000 Hertz.

Four sets of readings were taken (*) with a standard triode (tungsten filament $V_f = 4.0$ volt, saturation current 11 mA., anode potential varying between 100 and 200 volts, negative grid bias varying between — 4.5 and — 7.5 volt).

The applied E. M. F. $E \sin \omega_1 t$ was varied between 2.10^{-6} and 10^{-2} Volts, the resulting alternating grid voltage v_{g_1} with no retroaction varied between 100.10^{-6} and 0.5 Volts, and the resulting alternating grid voltage b with critical retroaction varied between ca. 0.2 and 4 Volts. The exponent S in the formula

$$b = (V_{g0}^2 \cdot v_{g1})^S$$

which, according to the above theory, should be

$$S = 0.33$$

was found from the four sets of measurements to be

$$\begin{array}{r} S = 0.36 \\ 0.36 \\ 0.36 \\ 0.32 \\ \hline \text{Mean : } S = 0.35 \end{array}$$

while the « grid space » V_{g0} calculated from these measurements was

$$\begin{array}{r} V_{g0} = 26 \text{ Volts} \\ 25 \\ 20 \\ 15 \\ \hline \text{Mean : } V_{g0} = 22 \text{ Volts,} \end{array}$$

as compared with the value

$$V_{g0} = 27 \text{ volts}$$

obtained directly from the characteristic.

Especially the experimental value for the exponent S fits in well with the theoretical value; provided only those parts of the characteristic are considered for which no oscillation hysteresis occurs. The representation of the i_a, v_g characteristic, by a cubical parabola, with three constants S_1, S_2 and S_3 only, obviously cannot yield very accurate values for V_{g0} obtained e. g. with the aid of a voltage swing of not more than 0.35 Volts.

Therefore, there is no doubt that for all practical purposes the theory expounded above fits in well with experiment.

Finally we give some practical figures calculated from formula (12) with the following data :

$$\frac{\omega L}{r} = 40,$$

$$V_{g0} = 27 \text{ Volts.}$$

Electromotive force *E* working in grid circuit.	Resulting alternating grid voltage with no retroaction (v_{g1}).	Resulting alt. grid volt. *b*, with critical retroaction.	Amplification obtainable through critical retroaction (b/v_{g1}).
10^{-6} Volts.	$0{,}04.10^{-3}$ Volts.	0,31 Volts.	7,700
10^{-5} »	$0{,}4\ .10^{-3}$ »	0,66 »	1,600
10^{-4} »	$4{,}0\ .10^{-3}$ »	1,4 »	360
10^{-3} »	0,04 »	3,1 »	77
10^{-2} »	0,4 »	6,6 »	16

Physical Laboratory
of Philips' Glowlampworks Ltd.
Eindhoven (Holland).

* * *

(*) The experiments and calibration of the necessary amplifiers were performed, by MM. K. POSTHUMUS and R. VELDHUYZEN. Care was taken that the « receiver » did not react on the « transmitter ».

The navy's primary frequency standard (1),

by Robert H. WORRALL and Raymond B. OWENS,
Naval Research Laboratory,
Washington (D. C., U. S. A.)

Synopsis. — In this paper is described a constant frequency source which is used as the Navy's primary working standard of frequency. This frequency source is a crystal controlled oscillator of special design which was developed at the United States Naval Research Laboratory, Washington, D. C. This oscillator employs a type of circuit which is rich in harmonics, over 200 of which may be used as fixed standard frequencies.

It also describes in detail the method employed to determine the fundamental frequency of this standard in terms of Naval Observatory time to an accuracy of about one part in 100,000. The ultimate standard of frequency is therefore the mean solar day.

History. — Several years ago when the Navy began to experiment with high frequency continuous wave radio communication, the Navy standard of frequency was an absorption type of wavemeter. It consisted of a precision condenser and a number of coils designed to have a constant inductance and a low radio-frequency resistance. A resonance indicator, if desired, could be loosely coupled to this circuit. This standard wavemeter was calibrated by means of the multi-vibrator or other oscillator whose output was rich in harmonics. The multivibrator in turn was adjusted to resonance with a standard 1,000 cycle tuning fork. By this means the wavemeter calibration could be maintained by frequent checking to an accuracy of one-tenth of one percent. For spark and low frequency continuous-wave transmission, precision of this order was satisfactory.

One of the first results of the advent of high frequency transmission was to indicate the inadequacy of a frequency standard the calibration of which might be in error by 0.1 °/₀ in either direction. For at a frequency of 10,000 kilocycles, this would mean a possible error of 10 kilocycles, plus or minus. Thus at this frequency a transmitter would occupy a band 20 kilocycles wide, which would increase interference between stations, or greatly decrease the number of communication channels by requiring a greater separation in kilocycles between assigned frequencies. Naturally a service wavemeter calibrated from this standard might conceivably be in error by a much larger percent than the standard itself.

Therefore there was presented to the Naval Research Laboratory for solution a three-fold problem : 1° to develop for the Naval service a frequency standard whose constancy should be as nearly absolute as possible; 2° to provide a means of obtaining direct from this standard a large number of fixed frequencies for calibration purposes; 3° to develop a method for determining the frequency of this standard in terms of observatory time to better than 0.01 °/₀, and as near 0.001 °/₀ as possible.

Crystal controlled oscillators. — The application of the piezo electric properties of quartz crystals to control the frequency of vacuum tube oscillating circuits, regardless of small changes in capacity or inductance, suggested a crystal controlled oscillator as the solution to our first problem. After experimenting with different types of circuits and making a number of refinements in crystal holders a crystal controlled oscillator was developed which with automatic temperature control was found to give an output of practically absolute constancy.

Tests have shown that the combined effect on the frequency of the standard oscillator caused by a five percent change in plate voltage is less than 0.001 °/₀. A ten percent change in filament voltage produces no noticeable change in frequency. Changing from one tube to another of the same type produces a change in frequency varying from zero to a maximum of about 0.002 °/₀. On account of the lack of uniformity in tube constants, several tubes that give the same frequency as the oscillator tube used in the calibration are kept as spares, which practically eliminates the error due to tubes. The temperature coefficient of the standard crystal in its holder is less than one part in one hundred thousand per degree centigrade.

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(1) Read by Dr. L. P. Wheeler.

Types of circuits. — One type of circuit used in the preliminary work was that shown in Fig. 1. This tuned plate circuit (1), using a small inductance and a relatively large capacity, gives maximum output on the fundamental frequency and a rapidly diminishing amount of energy on the harmonics. In other words, this is a transmitter type of circuit, and only a few harmonics could be used for calibration purposes. This circuit was therefore modified with the purpose of reducing the strength of the fundamental and intensifying the harmonics, so that each multiple of the crystal frequency could be used as a standard frequency. This modification consisted in replacing the tuned plate circuit, with a very large inductance having a small distributed capacity and no condenser across the coil. (See Fig. 2.) This untuned coil must have a natural frequency higher than the crystal fundamental; that is, it must be an inductive reactance at the crystal frequency to give the feed-back in the right phase relation to the grid potential to sustain oscillation.

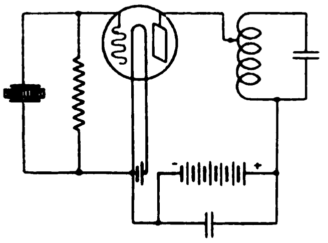
FIG. 1.

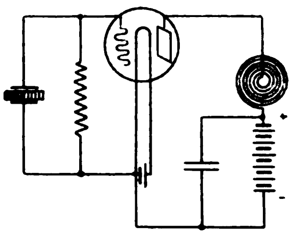
FIG. 2.

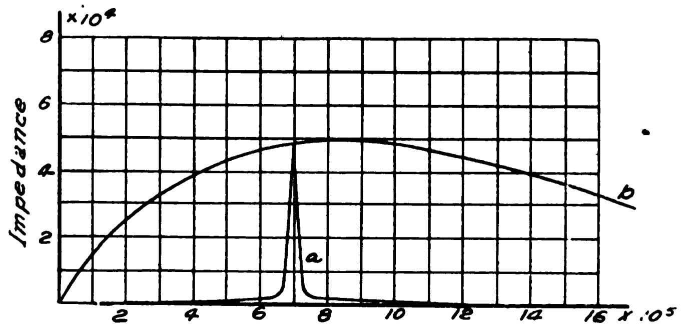

FIG. 3.

To bring out more clearly the difference in the strength of harmonics in these two types of plate circuits, it may be stated that the amount of radio frequency current in the plate circuit of an oscillator on a given harmonic frequency depends greatly on the ratio of the external impedance at this frequency to the internal plate impedance of the tube. When these impedances are about equal for a given frequency, we get the maximum energy on this frequency. If the external circuit impedance is small compared to the tube impedance at a given frequency the energy radiated at this frequency will be correspondingly small.

Now the tuned circuit with a low L/C ratio gives an external impedance of about the order of the tube plate impedance, or greater, over a narrow band of frequencies. (See Fig. 3*a*.) For instance, the external impedance is relatively very small at a frequency five times the crystal fundamental. Therefore this harmonic would be very weak in comparison with the energy radiated on the fundamental frequency.

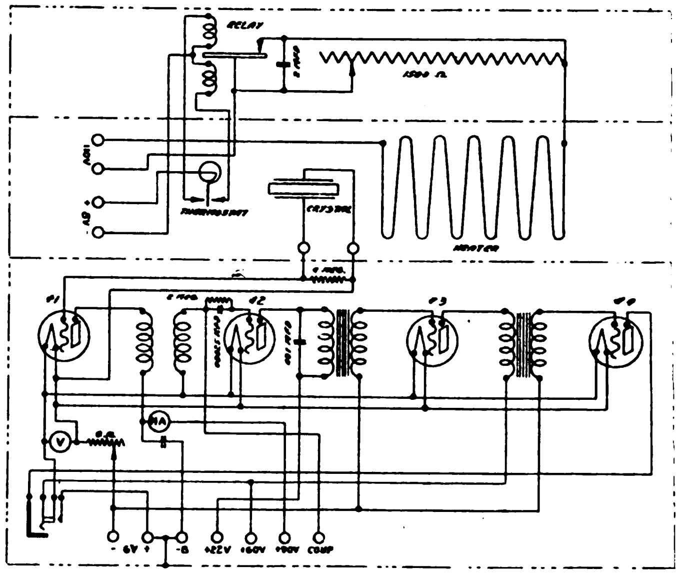

FIG. 4.

On the other hand, a coil with a large L/C ratio gives an impedance curve that is very broad, indicating that the strength of the fundamental and of a large number of successive harmonics will be of the same general order, as indicated in Fig. 3*b*.

This oscillator may be considered as a very low power crystal controlled transmitter radiating on perhaps two hundred frequencies each one of which is an integral multiple of the crystal fundamental frequency.

To make use of all these harmonics, as in the calibration of heterodyne frequency meters, it is necessary to couple this oscillator, as well as any oscillator to be calibrated from it, to a detector and amplifier. The crystal oscillator and the detector and amplifier are built into a single unit, which with the automatic temperature control device is called the *Crystal controlled standard oscillator.* (See Fig. 4.) The input of the detector is untuned and the coil is designed to respond to all frequencies without any adjustments. In practice, the coupling is fixed between the crystal oscillator circuit and the detector coil, and a coupling wire is run from the detector sufficiently close to the oscillator under calibration for coupling purposes. When the heterodyne frequency meter (or other type of continuously variable oscillator) is adjusted to within an audible frequency of any harmonic of the crystal oscillator, the beat note between these is rectified by the detector and amplified by one or two stages of amplification.

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(1) Developed by Dr. J. M. Miller.

The decrease in beat note strength between the successive harmonics of the crystal fundamental frequency and another oscillator is too slight to notice. The signal produced by the hundreth harmonic is of the same general order of audibility as that caused by the fiftieth, and the two hundredth harmonic gives a note of easily readable strength. This device is portable as illustrated in Figs. 5 and 6. At the Naval Research Laboratory the frequency of the standard crystal is 25 kcs. From this one crystal and the associated circuits, as just described standard frequencies are obtained every 25 kcs up to 5,000 kcs. For a high frequency range, another standard is provided with a crystal of a frequency of 250 kcs. These two frequency standards enable us to cover the entire radio frequency scale.

CALIBRATING THE STANDARD OSCILLATOR.

General description of the method used. — Now that a constant frequency source had been developed, capable of giving approximately two hundred points for calibration purposes, the final problem was to provide a means of determining the frequency of this standard to as near 0.001 °/₀ as possible.

The method that was finally decided upon lends itself particularly well to the calibration of low frequency sources, such as the 25 kc standard, but it is not limited to any such frequency. In brief, the method employed makes use of a motor-driven generator whose frequency is varied until some harmonic of the generator output gives « zero beat » with the fundamental of the crystal oscillator. Then the generator is operated at this exact frequency for some minutes during which time a record consisting of a dot per second is imprinted upon a sheet of paper on a revolving chronograph drum thru the medium of a striker actuated by an electrical circuit operated by a standard chronometer. From the slope of the lines of dots thus made on the chronograph drum, the frequency of the generator is very accurately determined. This frequency, multiplied by the number of the harmonic of the generator which was adjusted to the « zero beat » with the crystal oscillator, gives the frequency of the oscillator itself.

To make clear how the method works out in practice, a more detailed description of the apparatus and procedure follows :

Apparatus used in the calibration of the Crystal controlled standard oscillator.

1) A 500 cycle motor generator.
2) A very accurate chronometer.
3) A chronograph.
4) A Maxwell Bridge Circuit.
5) A circuit for the suppression of the 500 cycle fundamental of the generator and the accentuation of the harmonics of the 500 cycle fundamental.
6) A special amplifier.

1) The motor generator outfit consists of a five horse power D. C. motor connected by a heavy fly wheel to an alternator type 500 cycle generator, operated on a high capacity 110 volt battery. (See Fig. 7.)

2) The chronometer is a large Navy standard chronometer adjusted and periodically inspected at the Naval Observatory. The chronometer is checked daily at the Laboratory against the standard time signals. The original rate as

determined at the observatory was one and one-half seconds a day. Our observations covering several years show a slight seasonal variation in the rate, it being about one second a day in summer and one and one-half seconds in the winter. A correction chart has been plotted showing the rate for any time of the year. But when calibrations of the standard crystal are being made, the rate is determined from the daily check against the time signals.

3) The chronograph consists of the following units; the chronometer, a relay, a striker and a drum. The drum, Fig. 8, is a hollow brass cylinder about 7" in diameter and 16" long, accurately machined and geared to the generator by means of reduction gears, giving one rotation of the drum to 150 revolutions of the generator shaft. On this cylinder is placed a piece of paper upon which the striker referred to above makes a record as it moves along the face of the drum thru the medium of a worm. The striker records a dot upon the paper once a second (omitting the 59th second every minute) and is actuated by the chronometer. One rotation of the generator shaft corresponds to an alternating potential output of twenty cycles, as can be noted by counting the poles. Now when the drum, operated through the reduction gear just mentioned, rotates once in exactly six seconds, as indicated by six rows of dots exactly parallel to the axis of the drum on the record sheet, the generator frequency is $\frac{150 \times 20}{6}$ or 500 cycles per second.

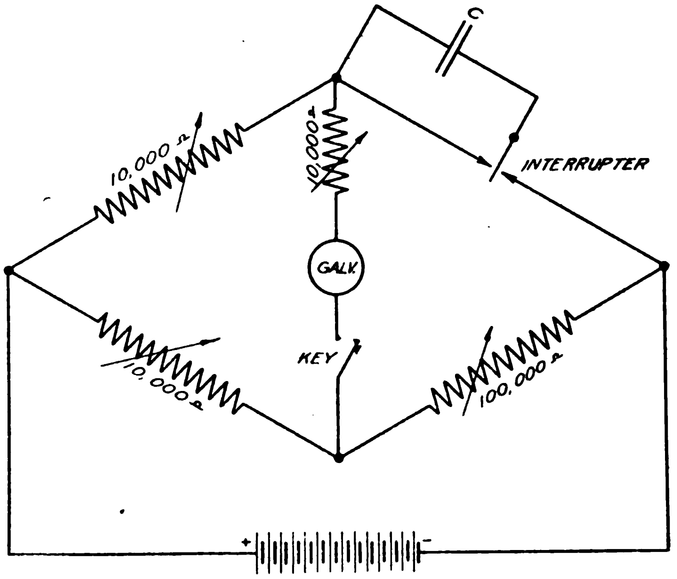

Fig. 9. – Maxwell Bridge Circuit.

If the rows of dots slope up the generator output is less than 500 cycles; if they slope down, it is more. From this chronograph record the exact generator frequency during a run is determined, as will be explained in detail further on.

4) The Maxwell Bridge, a diagram of which is shown in Fig. 9 is used in connection with the calibration of the standard crystal as an aid in maintaining the speed of the motor generator constant at the value desired.

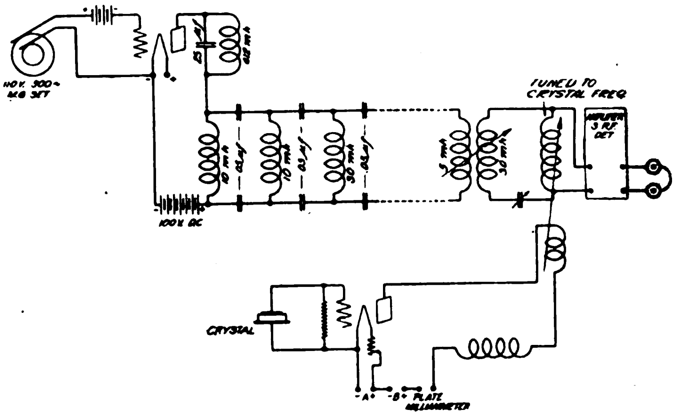

Fig. 10. — Crystal Calibrating Circuit.

The condenser shown in one arm, is charged and discharged from the battery across the bridge by means of a rotating interrupter driven from the generator shaft. The commutator segments of the interrupter operate thru three brushes to charge and discharge the condenser.

When the bridge is balanced at a given generator speed, the slightest variation from this speed causes a deflection of the beam of light reflected from the galvanometer mirror on a ground glass scale. The direction of the movement of the light beam indicates whether the generator is running too slow or too fast, thus enabling the operator to vary the pressue on the fly wheel to restore the generator speed to the zero beat condition.

This use of the generator, chronograph and Maxwell Bridge was patterned after the apparatus used at the Bureau of Standards (1) for the accurate measurements of small capacities.

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(1) *Bul. Bureau of Standards*, vol. III, ♯ 4.

5) The method of obtaining harmonics from the output of approximately 500 cycles is to impress this frequency upon the grid circuit of a vacuum tube, the plate circuit of which is rich in the required harmonics. As can be seen from Fig. 10 a tuned resonant circuit in the plate circuit partially absorbs the 500 cycle fundamental which, of course, is very strong The rest of the circuit consists of a filter designed to pass only the high frequency harmonics of the generator fundamental. This filter circuit terminates in a coupling coil which is coupled to a circuit tuned to the crystal frequency. This tuned circuit is also coupled to an amplifier by means of which the beats between the crystal and the generator harmonics are amplified and transmitted to the phones.

6) The amplifier consists of 3 radio stages and a detector.

Making a run. — The frequency of the standard crystal is first determined approximately by means of a standard Wave Meter. This is accurate to about 0.1 of 1 °/₀.

A sheet of paper is placed on the drum and the generator started up. After the generator has warmed up for about 30 minutes the phones from the amplifier shown in Fig. 10 are plugged into the generator room. The operator, with one hand on the Motor Generator flywheel varies the generator speed slightly from 500 cycles until some multiple or harmonic of it approaches the crystal frequency when beats are heard in the telephones. The operator now adjusts the speed until slow beats are heard. With the assistance of the other operator the Maxwell Bridge is balanced, which brings the light beam to rest on the scale. This is done while the first operator is controlling the slight changes in generator speed by changing the pressure upon the flywheel.

The only function of the Bridge is to indicate to the operator by the direction of the deflection of the beam of light whether fast beats in the phones represent an increase or a decrease in generator speed, so that he may quickly increase or decrease pressure on the flywheel to restore the generator speed to its proper value as indicated by very slow beats in the phones. The note in the phones is of the pitch of the generator fundamental frequency which fact may be made clear as follows : when any harmonic of the generator frequency is at zero beat with the crystal, the harmonics next above and below this one give a beat note with the crystal. If the harmonic at 25,000 cycles is tuned to the crystal, then the one at 24,500 and at 25,500 give a 500 cycle note with the crystal. Pulses or beats in this note indicate how much the 25,000 cycle harmonic differs from the crystal frequency. If a few beats are heard on the fast side, the generator speed is reduced just enough to give the same number of beats on the slow side of the zero beat position. A careful operator may thus compensate for slight changes in beat frequency during a run.

The operator now controls the generator speed to give as slow a beat frequency as possible for a few minutes before starting to record the run. When he notes that the machine is stable enough, he closes the chronometer circuit and the striker commences to put a record upon the paper mounted on the revolving drum. The time required to make a run varies from 8 to 15 minutes.

After the run the second operator may make a duplicate run upon the same harmonic, and then both operators make runs on another harmonic. No error due to the human element is observable in the results.

Obtaining the generator frequency. — Before removing the paper record from the drum a line is drawn on it parallel to the axis of the drum. The completed record will contain 6 parallel rows of dots since the drum makes one complete revolution in approximately six seconds, depending upon the frequency of the crystal. The striker puts a dot on the paper every second, while the carriage upon which the striker rests advances approximately 1 millimeter per revolution of the drum. One section of a completed record is shown in Fig. 11.

The method for computing the generator frequency is based on the fact that due to the number of poles in the generator and the ratio of the reduction gear between the generator and the chronograph drum as previously mentioned, a rotation of the drum in exactly six seconds corresponds to a generator frequency of exactly 500 cycles. That is. if the six parallel rows of dots printed on the drum thru the chronometer are parallel to the axis of the drum the generator is operating at 500 cycles.

If the slope of these rows of dots is up, the drum has not made a complete rotation in six seconds and therefore the generator speed is less than 500 cycles. A downward slope indicates more than one rotation of the drum in the six second interval or a generator speed greater than 500 cycles.

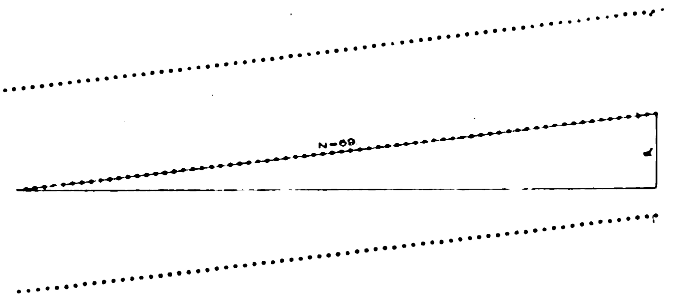

FIG 11

Assume for example that the the rows of dots are parallel to the axis of the drum. Then in 100 rotations a point on the surface of the drum would have traveled 100 times the circumference of the drum, 100 × 51.9 cm. This corresponds to a 500 cycle generator speed. By a simple proportion the generator frequency for any slope of line can be determined thus :

$$CN : CN \pm d = 500 : X$$

Where C = the circumference of drum.
N = number of rotations of the drum.
d = the perpendicular distance between the first and the last dot in a line.
X = the generator frequency.

The d above is the distance that the total run varies from being an even number of rotations of the drum. If the slope is up, d is negative; if down, the sign is positive.

Example :

$C = 51.9$
$N = 100$
$d = 0.3$ cm. Slope is up. Therefore d is minus.
Generator frequency = 499,971 cycles per second.

From the measurement of the crystal frequency by the standard wave meter, its value was found to be roughly 25 kc. Therefore it must have been the fiftieth multiple of the generator fundamental that was held during the run at the crystal fundamental frequency.

The crystal oscillator frequency is therefore fifty times the generator frequency or 24,998.55 cycles. If the generator speed should be increased sufficiently, a point will be found around 510 cycles where the zero beat condition may be again located by means of the phones. This is obviously the forty-ninth harmonic of the generator adjusted to the crystal frequency (510 × 49 = 25,000 approximately).

Accuracy of the method. — The accuracy of a calibration is chiefly dependent on the constancy to which the generator frequency can be held. To assist in this, the motor-generator is operated on a bank of high capacity storage batteries kept in good condition and fully charged. The machine is allowed to warm up thoroughly before a run is attemped. The Maxwell Bridge battery is also carefully checked for constant voltage, and the brushes and contactor segments in the Bridge circuit are kept clean and properly adjusted. As previously stated, slight variations in the generator frequency can be compensated for by the operator, but if the run is noticeably poor it is so recorded, or discarded.

The error arising from the measurement of the line d is minimized by determining it for all six parallel lines in a record, and using the mean as the correct value for d. The resulting error does not average more than one part in 200,000. The combined errors then, on a good run, are well within 0.001 °/o. This degree of accuracy is possible only when the crystal is left undisturbed. The accuracy claimed for the standard crystal oscillator when used as a portable standard is only 0.002 °/o. No error is observable due to a probable error in the measurement of the drum circumference.

To give an idea of the correspondence of different calibrations a table of eight consecutive runs on a standard crystal is appended. It will be noted that the probable error in the mean value is three parts in two and one half million.

Table of calibrations.

Date.	Temp. degree C.	Frequency, cycles.
8-15-27	38.45	24998.60
8-15-27	38.45	24998.75
8-16-27	38.45	24998.71
8-16-27	38.45	24998.73
8-29-27	38.55	24998.99
8-29-27	38.55	24998.82
9- 8-27	38.50	24998.71
9- 8-27	38.50	24998.63
	Mean value =	24998.74

Uses of the standard crystal controlled oscillator. — This standard oscillator is a portable device, the size being 8 × 14 × 22 1/2 inches. It is simple to use, there being no variables or tuning controls. It requires a plate potential of only ninety volts, and the heater may be operated on the 110 volt line. By its use, two hundred or more fixed frequencies equally spaced in kilocycles and accurate to about 0.001 °/₀ are made available. The permanence of the crystal calibration depends only on the permanence of the crystal itself.

This oscillator is used at the Naval Research Laboratory to standardize all quartz crystals manufactured there. Through the medium of a precision heterodyne frequency meter with a straight line frequency characteristic a crystal of any frequency can be calibrated from the standard oscillator to about 0.002 °/₀.

Furthermore, all heterodyne frequency meters for the Naval Service are calibrated directly against the harmonics of a standard oscillator. Readings may be taken as rapidly as the heterodyne frequency meter can be tuned to the successive harmonics of the crystal oscillator. For very accurate work, readings are taken on a beat note of 1,000 cycles (as determined by a tuning fork) on both sides of the zero beat point.

The calibration of a heterodyne frequency meter can be rapidly checked to determine the error at any time, by taking readings on a few harmonics of the crystal. For this purpose a special type of crystal oscillator without temperature control has been furnished the Fleet under the name of the « Crystal Controlled Calibrator », Navy Type ≈ SE 2907.

The standard oscillator may also be used for the inter-comparison of frequency standards. One such comparison has already been made between the Navy's standard crystal controlled oscillator and the Bell Telephone Laboratories' standard tuning fork, to determine the relative constancy and the agreement in calibration of the two standards. For this test, the Navy oscillator was transported to New York City. A number of oscillographic records of the beat frequency between harmonics of the two standards taken at intervals over a period of three days indicated that there was no noticeable variation in the relative constancy of the two sources. The determination of frequency by the two standards differed by one part in 80,000 or 0.0012 °/₀. This agreement is considered excellent when it is remembered that the Navy standard had been taken from Washington to New York for the test and that entirely different methods were used to calibrate the two standards.

Since this comparison with the Bell Telephone Laboratories' standard was made, this Laboratory has built four crystal controlled oscillators similar to the one described in this paper, as a part of a program for the establishment of a national secondary frequency standard decided upon at a conference in Washington in February of this year. This conference was attended by representatives of the various interested government departments, and of a number of the radio manufacturing companies.

It is hoped that, after a determination of the frequency of these oscillators at several other laboratories has been made, and an average result arrived at, that these oscillators may serve as useful secondary standards of frequency for the government and the radio industry of the country.

* * *

The Directional Observations on Atmospherics in Japan,

by EITARO YOKOYAMA and TOMOZO NAKAI,

Electrotechnical Laboratory, Ministry of Communications,
Tokyo (Japan)

I. *Introduction.* — Since February 1927, daily observations have been carried out on the directions of such atmospherics as to disturb the reception of long wave signals in our branch Laboratory at Isohama Town which is situated about 100 kilometers north-east from Tokyo and facing the Pacific Ocean. Though the duration of the observations has been too short to reach definite conclusions, we avail ourselves of this opportunity to bring the results before the Congress.

II. *Apparatus and method of observations.* — A Telefunken E-276-b type direction finder has been in use. This is a heterodyne receiver which consists of a three-stage radio-frequency amplifier, a detector and a two-stage audio-frequency amplifier, in combination with some replaceable circular loops, which are 0.85 meter in diameter and can be rotated about a vertical axis, for obtaining a wide range of wave lengths and a small vertical antenna which may give the receiver a unidirectional property. As 7,200 meters was the longest wave length to be received by the equipment, another loop has been prepared to cover longer wave lengths necessary for the present observations, and the vertical antenna replaced by a longer one. The vertical antenna was coupled with the loop by its loading coil, the resonance condition being found by a variable condenser in parallel with the coil. The loop had also a tuning-in condenser. By this set, heart-shape characteristics of reception can be easily obtained, the phase of induced emf. being adjusted by the tuning of each circuit, and the antenna effect adjusted by the degree of coupling of the coil.

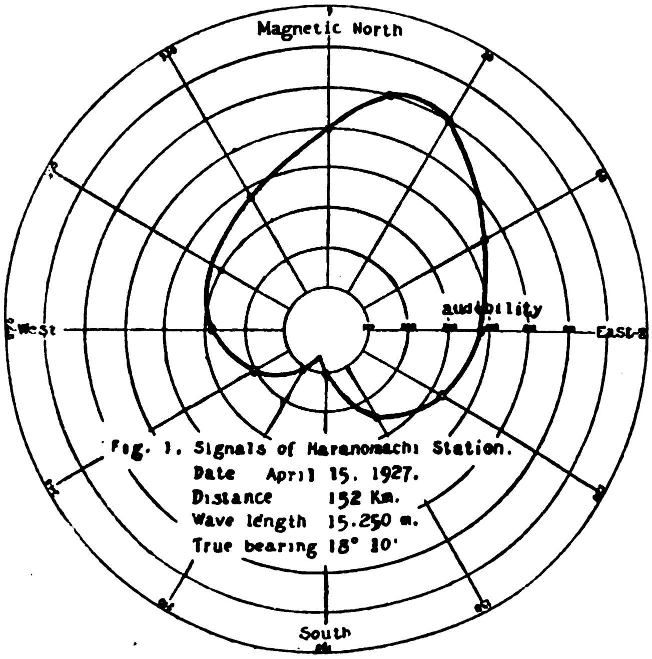

Fig. 1. Signals of Haranomachi Station.
Date April 15. 1927.
Distance 152 Km.
Wave length 15.250 m.
True bearing 18° 10'

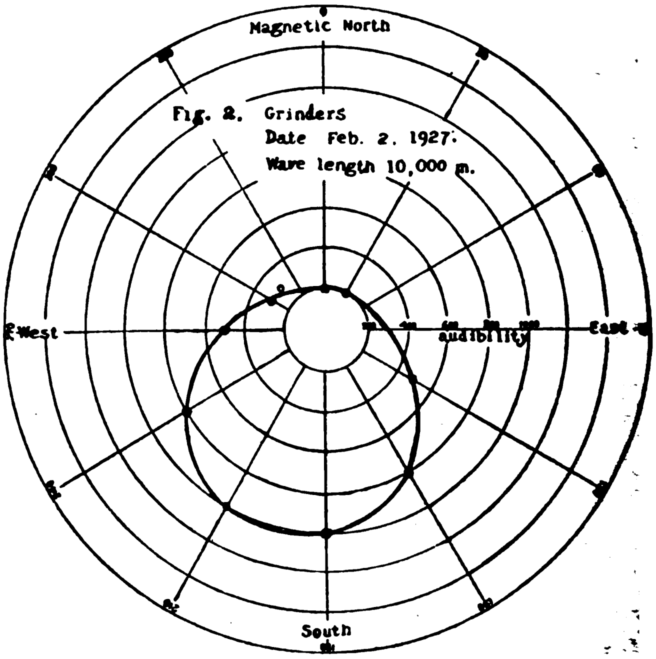

Fig. 2. Grinders
Date Feb. 2. 1927.
Wave length 10,000 m.

Atmospherics, especially those of the nature of clicks, generally change their strengths as well as their directions from moment to moment; thus it is not so easy to plot out their reliable polar curves for clicks or even for grinders. In order to simplify the procedure and to increase the accuracy in actual observations, a method of one-point observations has, therefore, been adopted, where a direction is first to be determined by turning the loop and by finding a minimum point of response; the sense is then to be decided by adding the vertical antenna to the loop, because a unidirectional combination will be liable to greater errors for direction finding than a loop only.

III. *Unidirectional polar curves.* — Fig. 1 is an example of the unidirectional polar curve for signal reception, and Fig. 2 that for grinders. As shown in the figure, no polar diagrams for atmospherics, as is well known, form heart-shapes at all, which is a phenomenon of interest for further studies.

IV. *Accuracy of the directional observations and correction for the apparatus.* — For the observations of strong signals, it has been found that the apparatus has an accuracy within one degree. But, for those of grinders, the band of minimum response was as wide as 2 degrees to 10 degrees and sometimes even reached 15 degrees, the width of the band depending upon the times of the day and the season, which might indicate that the seat of atmospherics covered a large area or moved from place to place. The middle points of the bands have, therefore, been taken as the directions of atmospherics. As clicks, which occur intermittently in short intervals of time and have much more variation in the observed directions, have been far more difficult for observations, it may be inferred that their accuracy has been much lower than those for grinders.

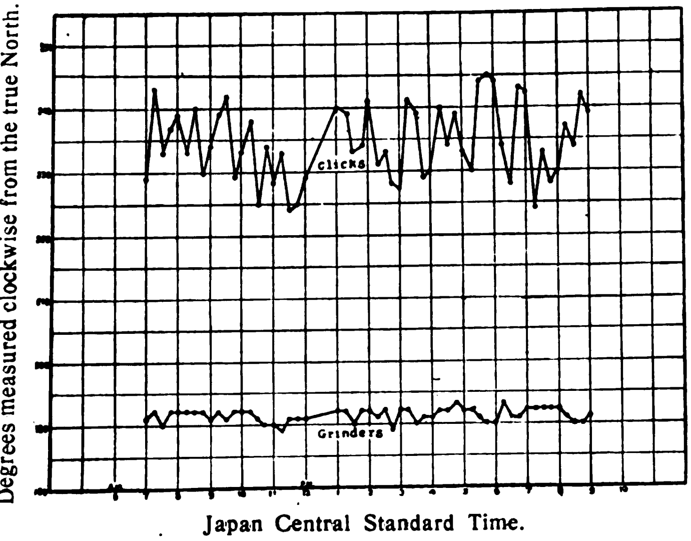

Fig. 3. — Diurnal variation in the directions of grinders and clicks in May 26, 1927. Wave length 10,000 m.

In addition to the above fact, there were present, in the surroundings of the measuring apparatus, several unremovable conductors which may give rise to some errors in the directional observations. For the rough correction of the effects, the bearings of several stations at known locations were observed and compared with their true bearings. It has thus been found that the maximum deviations were only one or two degrees, though the deviations were variable according to directions. On the figures in Table 1 below, no corrections have, therefore, been introduced.

Furthermore all the observations have been made by taking the bearings clockwise from the magnetic North in degrees. For finding out the similar bearings measured from the true North, the magnetic declination has to be taken into account. As the declination at the receiving station may be regarded as 5° 00' W. in average, corrections have, therefore, been made on the figures in table I below by substracting 5° from the observed bearings.

V. *Results of observations.* — 1) The observations were commenced at February 5. Until March 7, the observations of grinders only had been carried out on various wave lengths between 10,000 and 21,000 meters, about 10 times a day from 9.00 A.M. to 4.00 P.M. No appreciable variation due to wave lengths had however been noticeable, their amount being comparable to that of the diurnal variation observed on a particular wave length.

2) After the date, the observations have, therefore, been confined to two particular wave lengths, i.e., 10,000 meters and 20,000 meters. However no appreciable change in the observed directions has been noticed between the two.

3) After March 16, the time of observations has been extended from 7 A.M. to 9 P.M., observations being made at nearly every 30 minutes. The variation has, in general, been less in the day-time than at night, though it has not been so remarkable as in the case of signal observations. This seems to indicate that the seat of atmospherics is not invariable.

4) Since April, clicks have been observed in addition to grinders. The directions of clicks have been found to be obviously different from those of grinders, and the diurnal variation in the directions of clicks to be much greater than

those of grinders. One example of the diurnal variations in the directions of grinders and clicks is shown in Fig. 3. This seems to indicate that the seat of clicks differs from those of grinders.

5) From the observations on grinders from February to July, it may be said that they have not almost changed their directions during the season of the year and come from SSW (about 190°).

6) From the observations on clicks from April to July, it may be said on the contrary that their bearings have gradually shifted clockwise, though they were generally indistinct since the middle of June. This indistinctness seems to indicate that the seat of clicks is vastly extended in summer season.

The results of the observations are shown in Table I, the readings of directions being expressed in degrees measured clockwise from the North.

TABLE I. — *Directions of Atmospherics at Isohama.*

Date J. C. S. T. (1)	Direction of Grinders Mean	Max.	Min.	Direction of Clicks Mean	Max.	Min.	Field Intensity of atmospherics in μ v/m.
Feb., 5.	191	193	189		no obs.		
» 21.	191	197	185		»		
» 23.	189	192	180		»		
» 26.	190	193	187		»		
» 28.	191	193	190		»		
average =	190						grinders = 33 clicks = 1,198
March, 3.	190	192	187		no obs.		
» 7.	187	193	183		»		
» 9.	185	202	169		»		
» 16.	185	198	179		»		
» 24.	188	205	170		»		
» 31.	189	203	181		»		
average =	187						grinders = 26 clicks = 1,209
April, 7.	192	195	188	202	205	199	
» 14.	191	195	186	215	225	199	
» 15.	192	204	185	243	255	230	
» 16.	191	194	189	225	230	220	
» 21.	192	194	189	234	240	227	
» 28.	192	193	190	232	245	225	
average =	192		average =	225			grinders = 42 clicks = 2,050
May, 5.	191	193	189	225	250	205	
» 12.	192	193	190	237	251	223	
» 19.	191	193	189	236	247	225	
» 23.	192	194	190	235	245	227	
» 26.	191	193	189	235	245	224	
average =	192		average =	234			grinders = 52 clicks = 1,430
June, 2.	191	195	185	237	253	222	
» 9.	191	196	188	239	252	225	
» 23.	193	202	189	no distinct directions.			
» 27.	191	200	185	250	254	245	
» 30.	191	200	185	no distinct directions.			
average =	191		average =	242			grinders = 55 clicks = 3,100
July, 7.	190	199	180	directions obscure.			
» 14.	192	198	183		»		
» 21.	193	196	190		»		
» 23.	—	—	—	300	obscure.		
» 28.	192	194	190	270	280	260	
» 30.	—	—	—	270	280	260	
average =	192		average =	280			grinders = 59 clicks = 3,080

---

(1) Japan Central Standard Time.

To get an idea, in Table I are added the field intensities of atmospherics in microvolts per meter. The intensities have been daily measured with a different vertical antenna and the figures given in the table are the monthly average values (wave length = 15,600 m) measured at 4.30 P.M., by which atmospherics may be considered to be most prevalent. The intensities of grinders are those of signals which will be just readable through the grinders while the intensities of clicks are those of artificial clicks which can be regarded equal in strength to the natural clicks.

VI. *Results obtained by other observers.* — T. Nakagami of the Ministry of Communications, Tokyo, described in one of his papers regarding directions of atmospherics observed at the Osaka station in 1924-1925 as shown in Table II, in which the directions are expressed in angles measured clockwise from the North in degrees.

TABLE II. — *Directions of Atmospherics at Osaka.*

Month	Direction of Atmospherics at 18,000 m.
January	220° (S W)
February	200° (S S W)
March	200° (S S W)
April	250° (W S W)
May	315° (N W)
June	350° (N N W)
July	30° (N N E)
August	45° (N E)
September	40° (N N E)
October	20° (N N E)
November	300° (W N W)
December	240° (W S W)

J. Obata of the Aeronautical Research Institute, Tokyo Imperial University has also carried out some observations on atmospherics in Tokyo, commencing in July, 1926, the results of which are shown in Table III.

TABLE III. — *Directions of Atmospherics at Tokyo.*

Month	Direction of Atmospherics at 10,000 m.
August, 1926	N W — W N W
July, 1926	
September, 1926	W N W - W
October, 1926	S S W
November, 1926	S S W
December, 1926	No obs.
January, 1927	S S W
February, 1927	S S W
March, 1927	S S W — S W
April, 1927	No obs.
May, 1927	No obs.
June, 1927	W

The results obtained by the above two observers will now be compared with ours. According to their observations, the bearings began to rotate clockwise from SSW in winter, arrived at the furthest in summer and then came back counter-clockwise until the original bearing was again reached in winter, one cycle being completed in one year. In our observations, the bearings for clicks have been tracing a similar variation, while those for grinders have remained unchanged. This fact will probably indicate that the two sets of observations above mentioned were those for clicks.

VII. *Conclusions.* — From the results of the observations mentioned above, the following conclusions may be arrived at.

1) No appreciable change has been found in the observed directions of atmospherics by the variation of wave lengths which lie between 10,000 and 20,000 meters.

2) On the diurnal observations 7 A.M. to 9 P.M., no appreciable regular change has been noticeable in the observed directions of atmospherics by the time of day. Though some expected variations have, in general, been noticed at sunrise, sunset and night-times, they have not been so remarkable as in the case of signal observations.

3) The directions of clicks have been obviously different from those of grinders, which seems to indicate that the seat of clicks differs from those of grinders.

4) The diurnal variation has been much greater in the directions of clicks than in those of grinders. This seems to indicate that the seat of clicks lies nearer to the observed region than those of grinders, if the seats of both kinds of atmospherics might be assumed to have nearly equal areas. Judged from the great differences

in the intensities, as well as in the nature of tones of clicks and grinders, this assumption may be considered to be probable.

5) The directions of clicks have shifted from nearly South toward West as the season advanced from winter to summer, while those of grinders have remained unchanged.

6) In summer, the clicks, which seem to originate from the mountain regions of Japan, seem to be most prevalent, while grinders probably come always from a tropical region such as the East-Indies.

Acknowledgement is due to K. Ichikawa and A. Moriyasu of this laboratory for their earnest assistance through the experimental works.

August, 1927.

* * *

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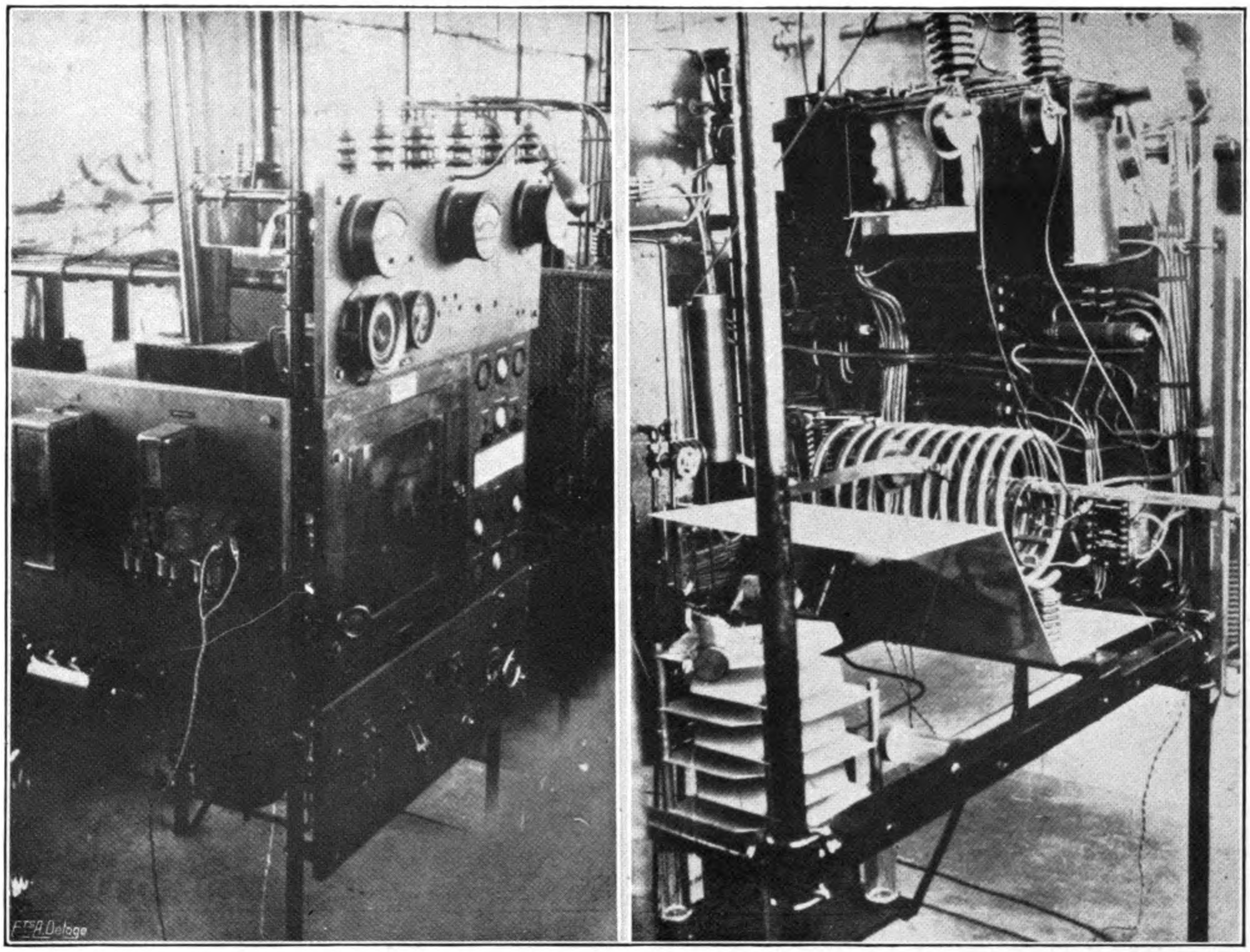

FIG. 3. — Views of transmitting apparatus.

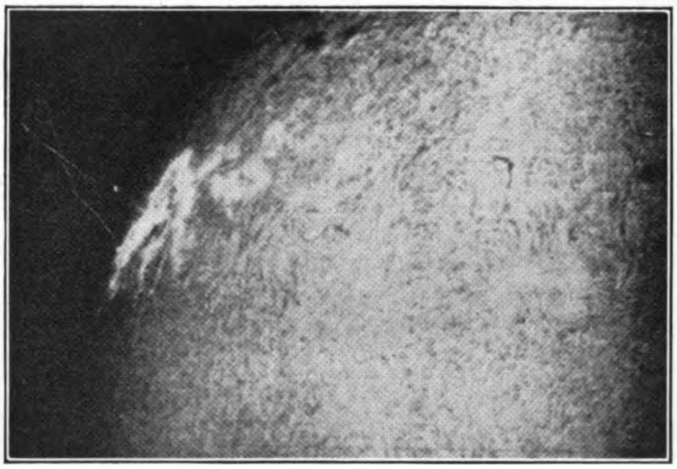

FIG. 6. — H-alpha image of sunspot-group photographed at Mount Wilson, August 19, 1927, 14h44m Greenwich mean time.

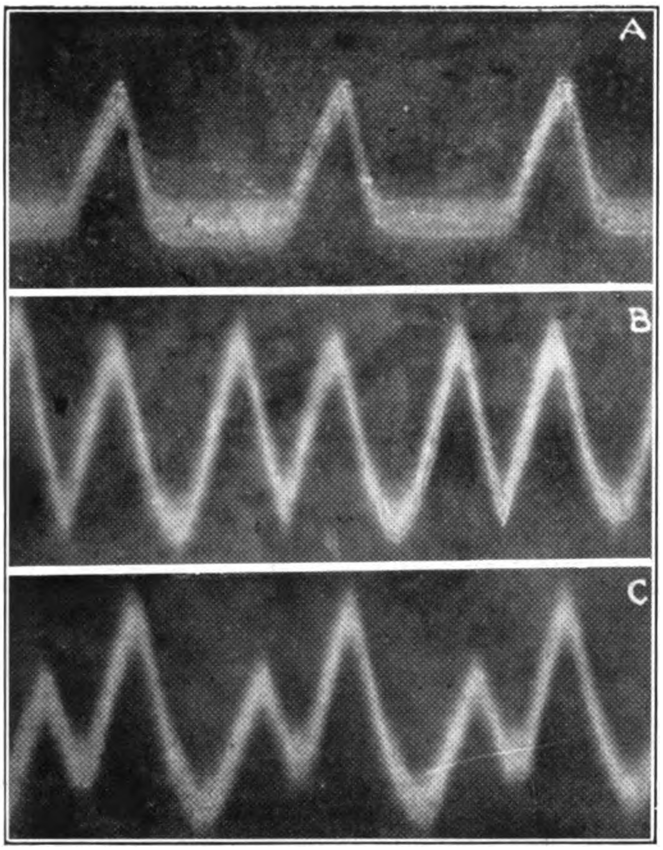

Fig. 4. — Wave-forms observed on August 25, 1927.

[(A) Reflection absent, showing wave-form of transmitter. — (B) Reflection approximately as strong as the ground-wave. — (C) Reflection weaker than ground-wave.]

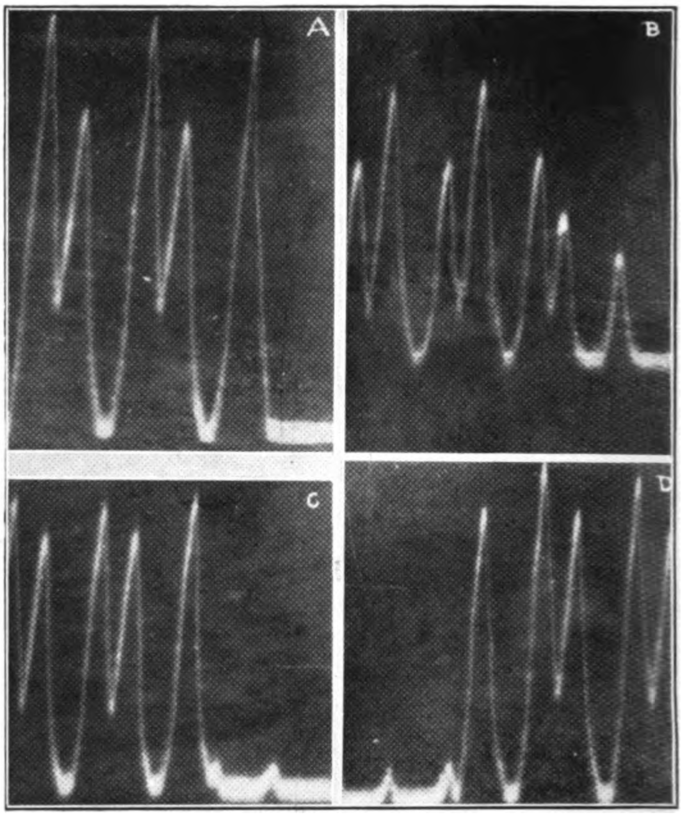

Fig. 5. — Wave-forms observed on October 8, 1927.

[(A) End of dot, reflection bigger than ground-wave, no key-click. — (B) End of dot, reflection smaller than ground-wave, last ground-hump weaker than preceding ones as also its reflection and in the right proportion. — (C) End of dot, reflection slightly bigger than ground-wave; note small key-click giving diminutive ground and reflected humps; time-separation between clicks same as between big humps. — (D) Beginning of dot, key-click arrives first along ground, then as a reflection, then big ground-hump, its reflection, etc.; separation checks as in (C). Note that amplitude of ground-hump is constant for all.]

G. FERRIE et R. JOUAUST, pp. 21-28.

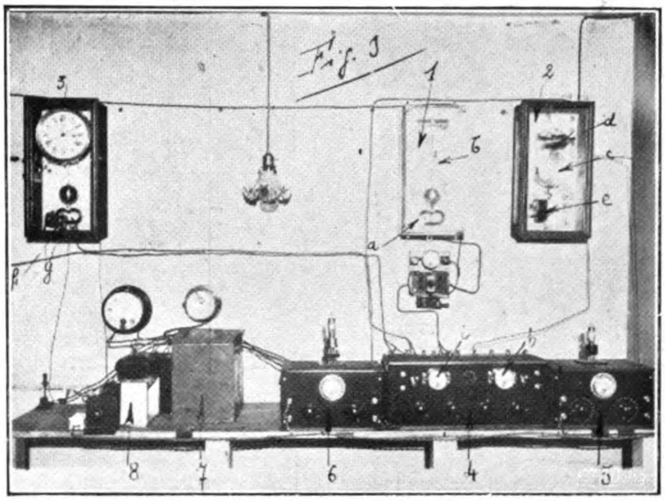

Fig. 3.

1. Pendule libre auto-entretenu.
    - *a*) Enroulement d'entretien.
    - *b*) Miroir.
2. Dispositif.
    - Cellule photoélectrique (*c*).
    - Source lumineuse (*d*).
    - Volet d'escamotage (*e*).
3. Pendulette compteur avec sa bobine d'auto-entretien (*f*), et ses bobines de synchronisation (*g*).
4. Boîte d'amplification du courant photoélectrique.
    - *h*) Milliampèremètre du courant d'entretien du pendule libre.
    - *i*) Milliampèremètre du courant de synchronisation de la pendulette.
5. Boîte d'alimentation de la tension cellule sur le courant alternatif.
6. Boîte d'alimentation de la tension plaque des lampes de l'amplificateur sur le courant alternatif.
7. Accumulateurs de chauffage des lampes de (4) et de manœuvre du volet (*e*).
8. Dispositif de charge continue des accumulateurs sur le courant alternatif.

J. W. HORTON and W. A. MARRISON, pp. 28-37.

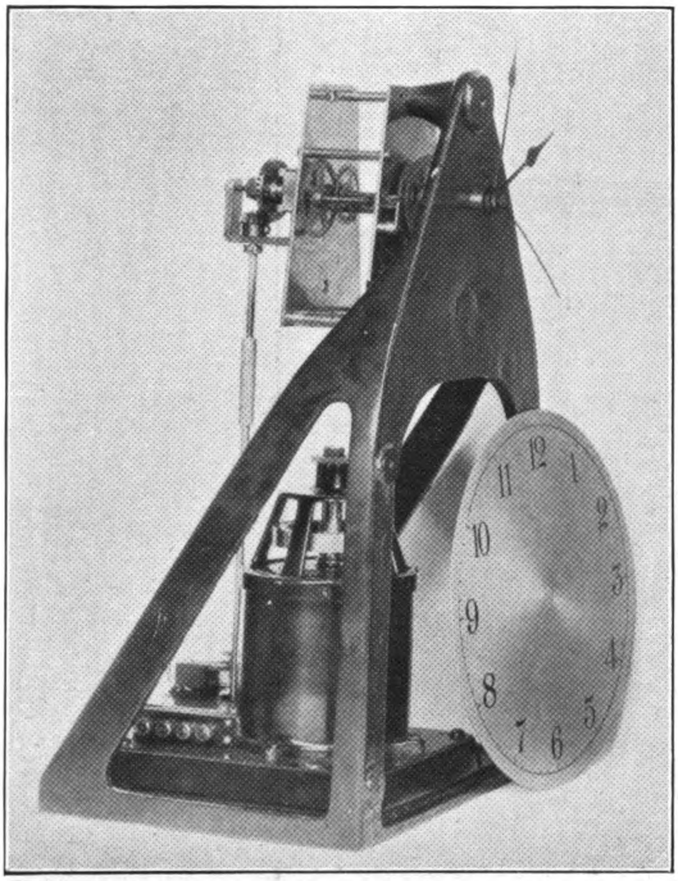

FIG. 1. — 100 Cycle Synchronous Motor Geared to Clock Train.

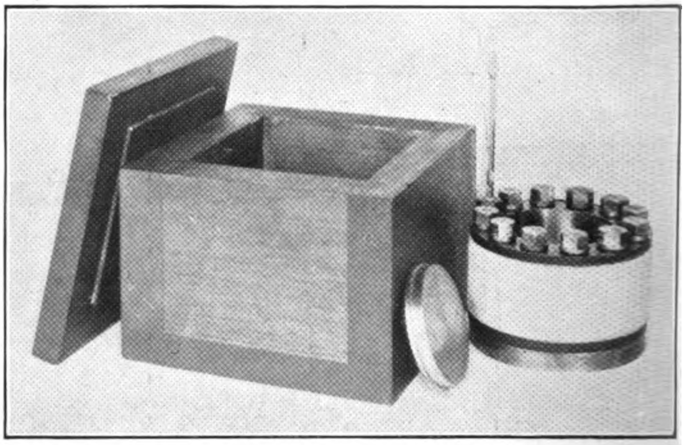

FIG. 7. — Thermostat for Piezoelectric Plate.

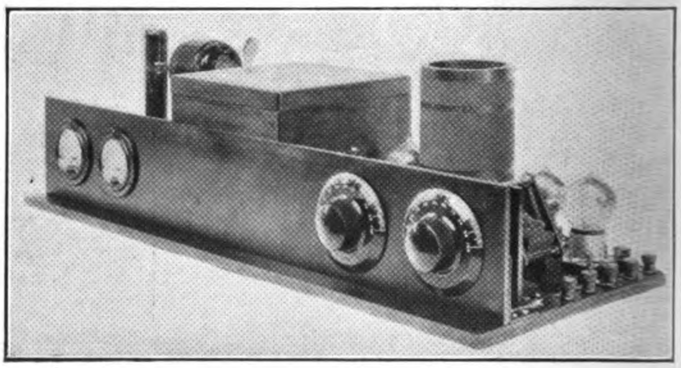

FIG. 8. — Standard 50,000 Cycle Oscillator.

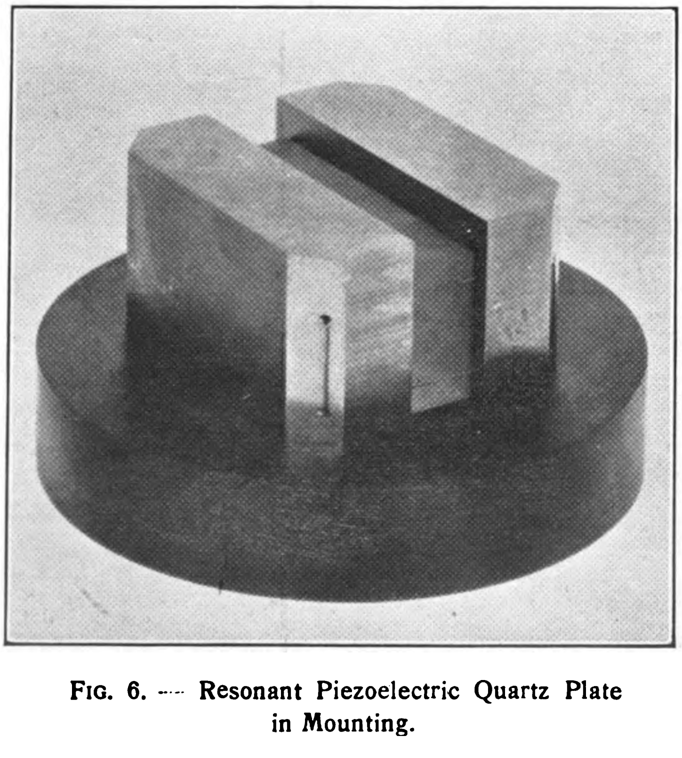

FIG. 6. — Resonant Piezoelectric Quartz Plate in Mounting.

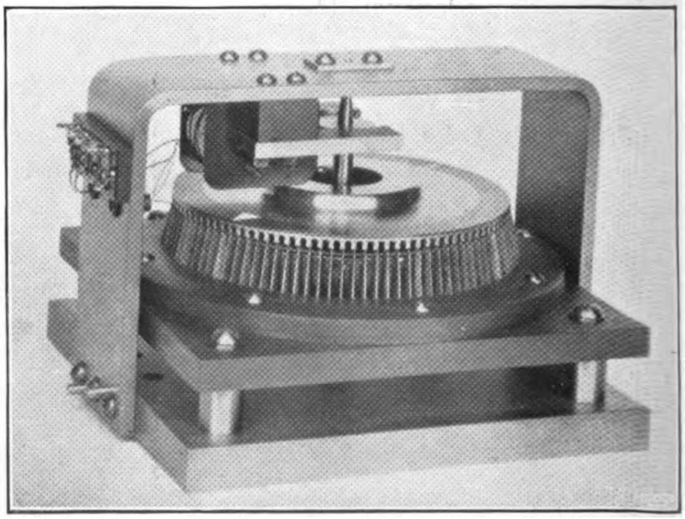

FIG. 11. — 5,000 Cycle Synchronous Motor.

E. B. JUDSON, pp. 38-40.

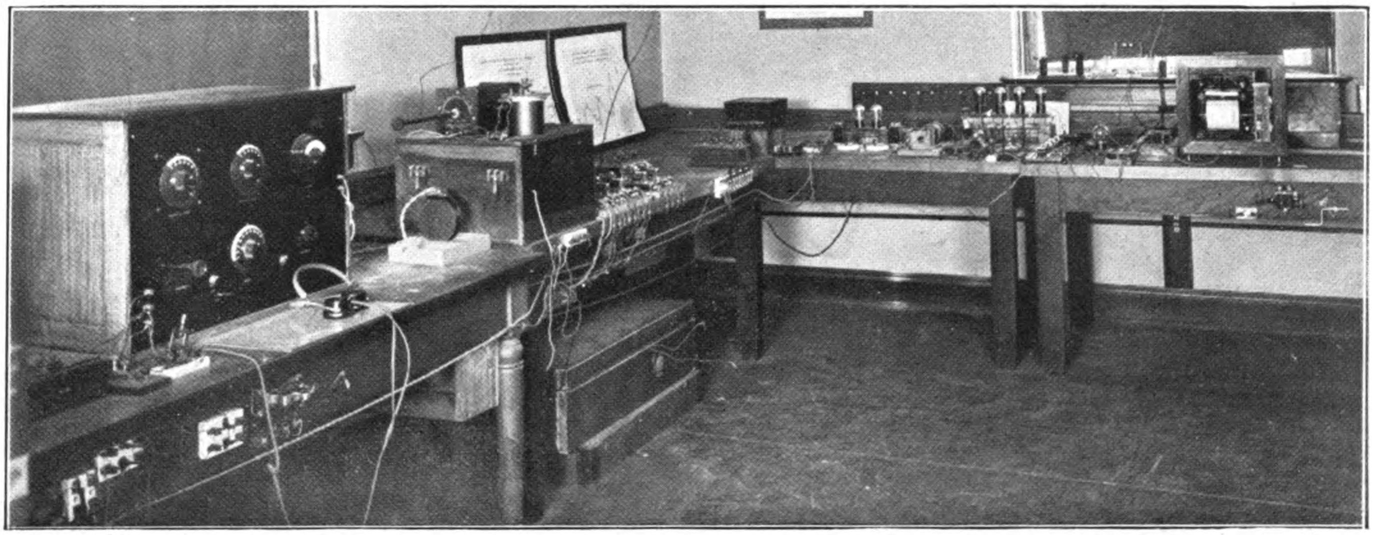

FIG. 2.

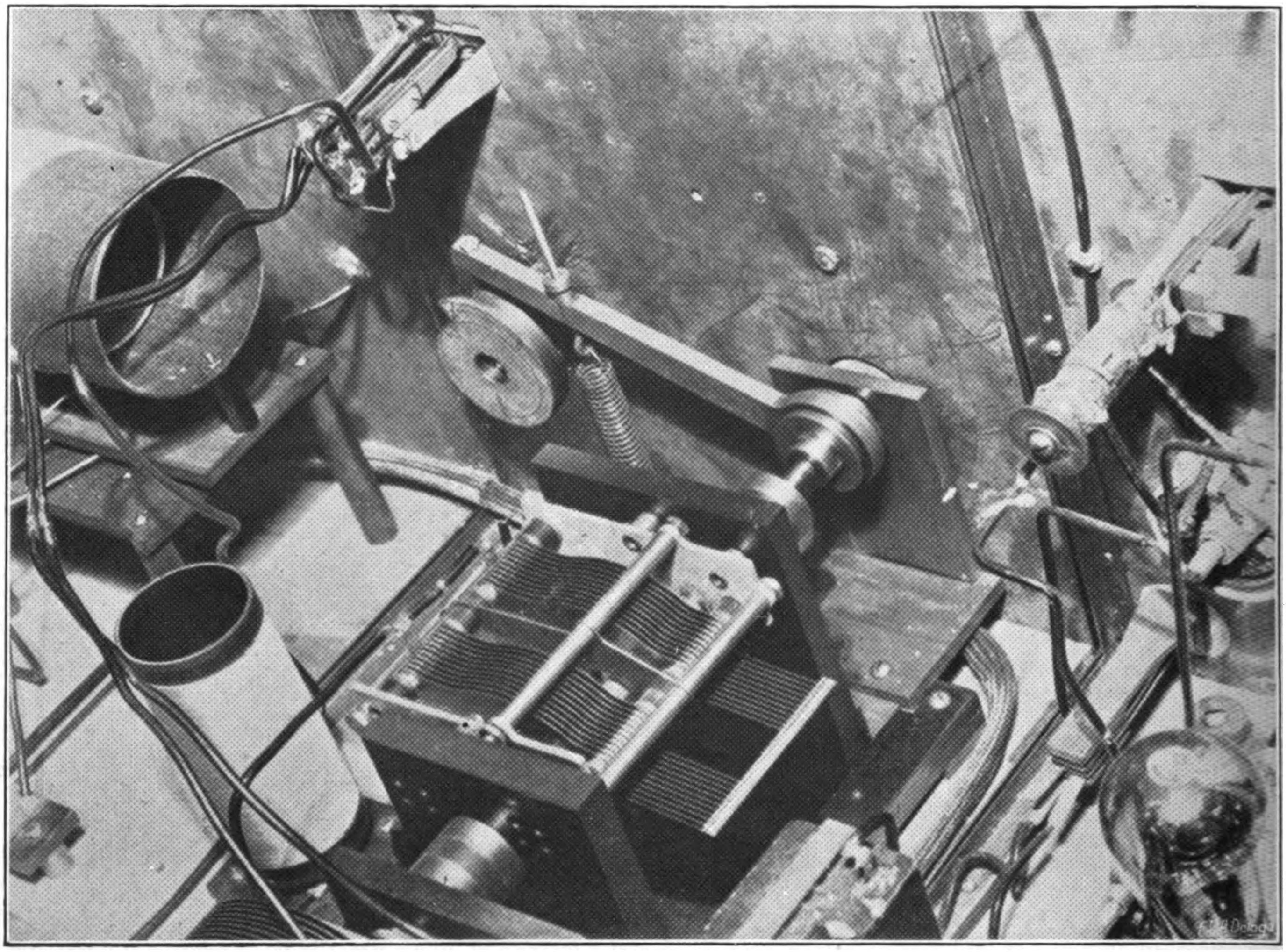

FIG. 8.
View of Cam and Main Tuning Condenser.

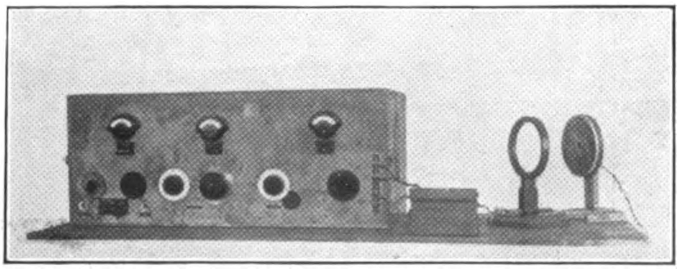

FIG. 9.
External View of the Completed Apparatus.

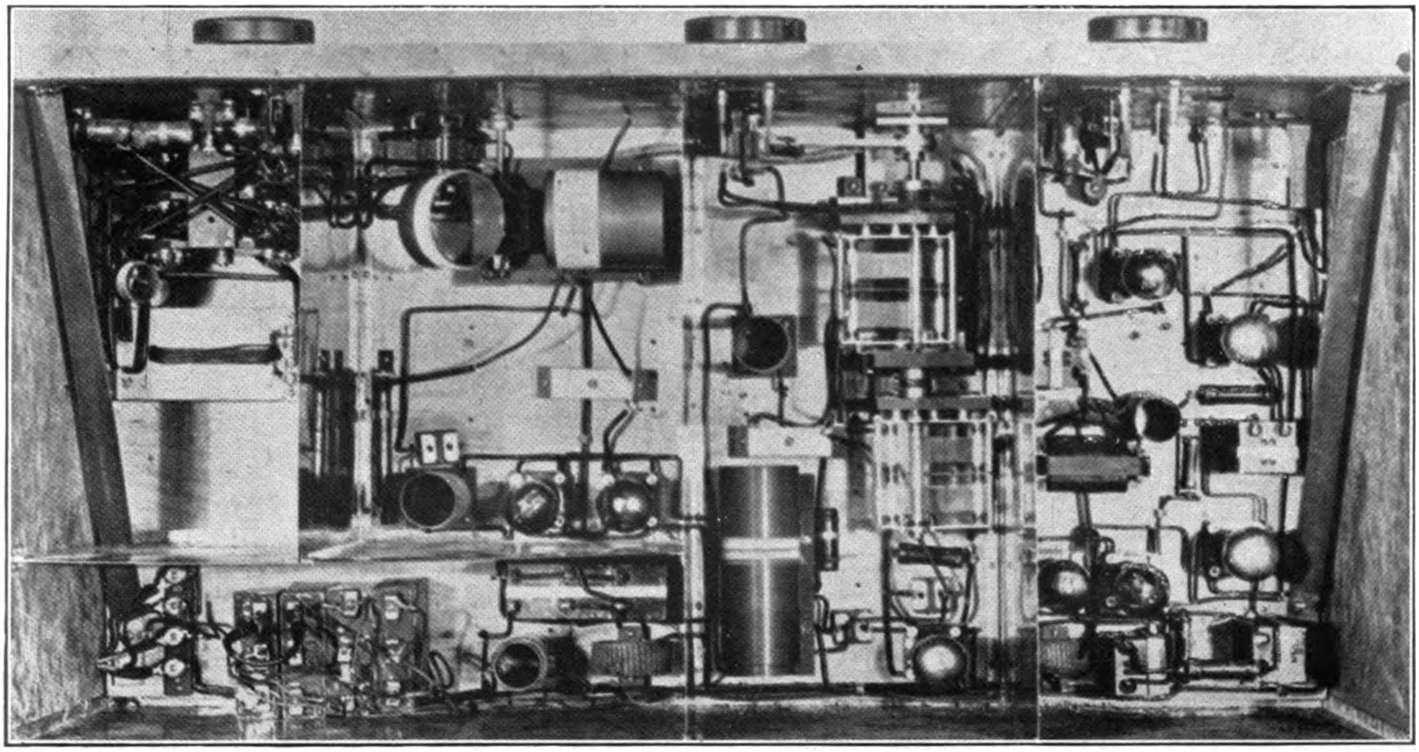

FIG. 10.

Internal View of the Complete Apparatus.

ROBERT H. WORRALL and RAYMOND B. OWENS, pp. 67-73.

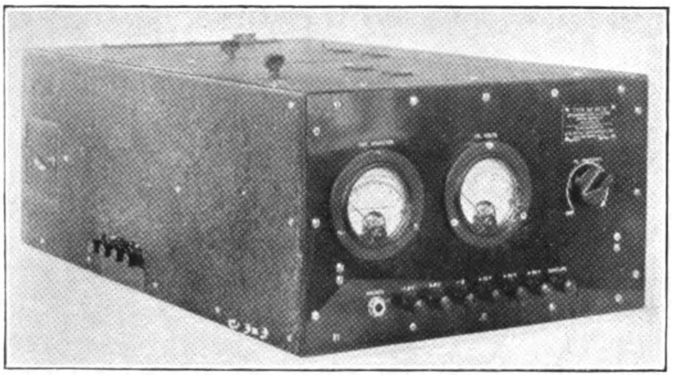

FIG. 5.

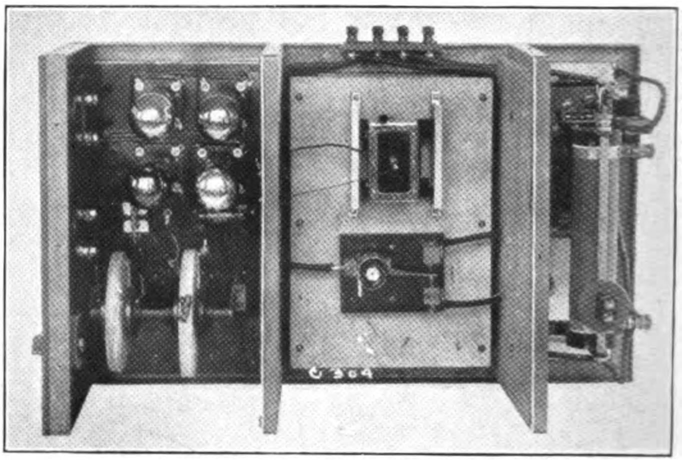

FIG. 6.

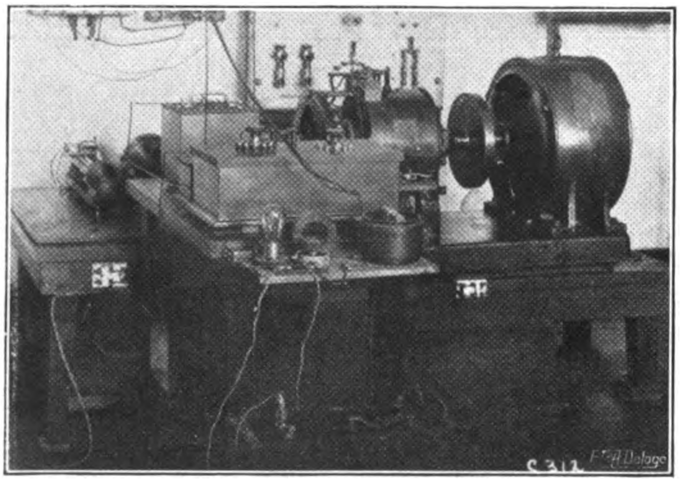

FIG. 7.

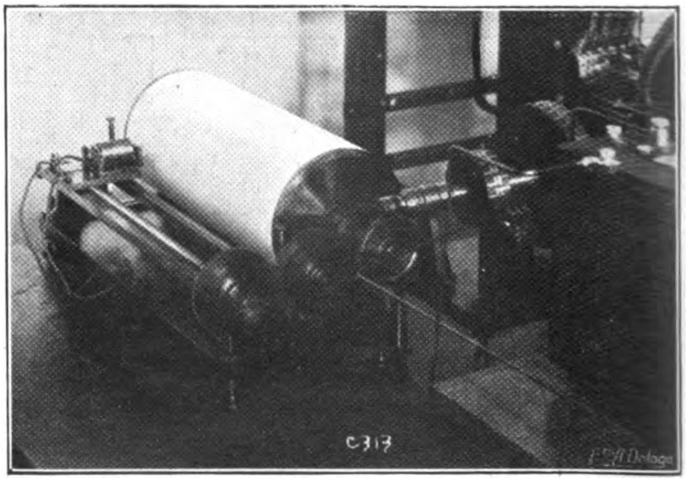

FIG. 8.

Mai
May 1929 VOL. II Fascicule 1

Union Radio Scientifique Internationale

International Scientific Radio Union

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Papers of the General Assembly held in Brussels in September 1928

MÉMOIRES SCIENTIFIQUES

présentés à la Séance publique du 13 Septembre 1928

TEXTES ORIGINAUX

SCIENTIFIC PAPERS

presented in the Public Session of September 13th, 1928

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Séance publique du 13 Septembre 1928

Public Session of September 13, 1928

La séance est ouverte par M. le Profr Th. De Donder, Président du Comité Belge de l'U.R.S.I., qui prononce le discours suivant :

Mesdames, Messieurs,

Au nom du *Comité National Belge de Radiotélégraphie Scientifique*, je tiens à exprimer ici nos plus vifs remerciements à tous ceux qui ont répondu à notre appel, aux savants éminents qui présenteront leurs travaux aujourd'hui, ainsi qu'aux nombreuses personnalités du monde radio-scientifique qui nous font l'honneur d'assister à cette réunion.

C'est la première fois qu'une séance publique de l'U. R. S. I. est organisée en Belgique, et nous sommes fiers de constater que cette tentative s'annonce sous les meilleurs auspices.

Comme vous le savez sans doute, Mesdames et Messieurs, l'*Union Radio Scientifique Internationale* est une enfant d'après-guerre. Elle émane de la *Commission Internationale de Télégraphie Sans Fil Scientifique* (T.S.F.S.), créée en 1913, à l'initiative de M. Robert Goldschmidt et de M. le Profr Schmidt, et dont l'activité naissante fut forcément interrompue par la guerre. En 1919, la réorganisation de cette Commission fut décidée et l'on fonda, au sein du *Conseil International de Recherches*, la présente *Union Radio Scientifique Internationale* (U. R. S. I.). Une Assemblée Générale eut lieu à Bruxelles en 1922 et l'activité de l'U. R. S. I. se développa rapidement : émissions et mesures d'intensité de signaux internationaux, échanges de documents, mise en circulation de références bibliographiques, publications de travaux de l'Union, etc. La coordination du travail et la préparation des assemblées sont assurées par le Secrétariat Général, dont le siège a été fixé à Bruxelles.

Un essor nouveau a été donné à l'U. R. S. I. depuis la dernière Assemblée Générale, tenue à Washington en 1927, et, grâce aux concours qui nous viennent de tous côtés, nous sommes convaincus que dans un avenir prochain, l'U.R.S.I. occupera une des premières places parmi les Associations Scientifiques Internationales.

Jusqu'à présent, l'activité de la Radio-scientifique en Belgique a été limitée aux efforts de quelques sociétés industrielles, aux travaux des clubs d'amateurs et aux trop rares contributions des laboratoires de recherches, qui en sont encore à leurs débuts ou qui, faute d'argent, ne peuvent réaliser qu'une faible partie de leur programme. Notre pays manque de jeunes chercheurs pouvant se consacrer à des travaux désintéressés. Les bonnes volontés existent; mais, jusqu'à présent, elles n'ont pu se manifester avec leur plein rendement.

Heureusement, une ère nouvelle s'ouvre devant nous. Vous connaissez tous l'admirable initiative prise par le Roi des Belges, en créant le *Fonds National de la Recherche Scientifique :* en quelques semaines ce Fonds a recueilli des dons s'élevant à plus de 100 millions de francs.

Il est bien certain que le Comité Belge de l'U.R.S.I. est tout désigné pour donner des directives concernant l'utilisation des subventions que ce Fonds accordera à la Radio expérimentale ainsi qu'à la Radio théorique.

Nul doute que sans la théorie des phénomènes de radiation électromagnétique, la Radiotélégraphie risquerait de se perdre dans d'infimes perfectionnements d'ordre technique. Qu'il me soit permis de rappeler que les ondes hertziennes sont nées, entre les mains de Hertz, de l'étude mathématique des équations de *Maxwell* et plus spécialement du mystérieux « courant de déplacement » dû au génie de ce grand physicien anglais.

Récemment, les ondes électromagnétiques ont été associées à de non moins mystérieux quanta de lumière, aussi appelés « photons ». D'innombrables mémoires ont été consacrés à ce nouveau monde physique, intermédiaire entre l'électron et l'éther. Les espérances les plus vastes et les plus hardies sont permises à l'heure actuelle. Il suffira de citer l'*effet Compton*, c'est-à-dire la décomposition des lumières dites simples; je pense aussi à l'onde éthérée de de Broglie qui se propage avec une vitesse plus grande que celle de la lumière; enfin, pensons aux réactions chimiques entre les photons et les électrons. Tout nous porte à croire que la Radio changera complètement d'aspect dans un avenir prochain, grâce à ces vues nouvelles.

MESDAMES, MESSIEURS,

La T. S. F. est non seulement un remarquable instrument de découverte, elle est aussi un instrument merveilleux de communication entre tous les hommes. Grâce à la subtilité prodigieuse des phénomènes radio électriques, les distances n'existent plus, toutes les pensées, au même instant, se pénètrent. Certes, il n'est pas de moyen plus apte à rapprocher les hommes et à leur faire sentir qu'ils se doivent tous à un même idéal. Nous voici, Mesdames et Messieurs, transportés loin, bien loin: j'ai été entraîné par les ondes électromagnétiques et bien d'autres encore.

Laissez-moi, en terminant, adresser un public hommage à notre Président, M. le Général Ferrié, et à notre dévoué Secrétaire Général M. Robert Goldschmidt.

M. De Donder prie ensuite M. le Général Ferrié d'accepter la Présidence de la Séance Publique.

Il est ensuite donné lecture des mémoires dont le texte est publié ci-après.

THE DEPENDENCE OF THE FREQUENCY OF QUARTZ PIEZO-ELECTRIC OSCILLATORS UPON CIRCUIT CONSTANTS

by Earle M. TERRY
Professor of Physics, University of Wisconsin.

The use of quartz piezo-electric oscillators, as first described by Cady (*), for stabilizing the frequency of triode driven circuits, has been of inestimable value in the maintenance of frequency standards and in holding radio transmitters on their assigned frequencies. Investigation has shown that the frequencies of such oscillators are, however, subject to certain variations, the chief causes of which are changes in temperature of the quartz plate, methods of mounting it, and the reactions of the electric circuit upon the mechanical properties of the quartz itself. By use of suitable thermostatic devices and by standardization of mountings, the first two sources of error have been brought under very good control, but the extent of which the frequency is influenced by the elements of the system of which the crystal forms a part has not as yet been fully investigated, and it is to supply this need in certain of the more commonly used circuits that the following work has been carried out.

Van Dycke (*) has shown that a piezo-electric quartz crystal is equivalent electrically to an inductance, a capacitance, and a resistance joined in series, as shown in figure 1, with a second capacitance shunted across them, and has given formulae by which these equivalent electrical quantities may be computed for any of its normal modes of oscillation from the dimensions of the crystal.

Using this method of representation, Dye (**)

(*) CADY, W. G., Piezo-electric Resonator, (*Proc. I. R. E.*, vol. 10, p. 83, 1922.)

(*) VAN DYCKE, K. S., The Piezo-electric Resonator and its Equivalent, (New York, *Proc. I. R. E.*, vol. 16, p. 742, 1928.)

(**) DYE, D. W., Piezo-electric Quartz Resonator and Equivalent Electrical Circuit. (*Proc. Phys. Soc.* London, vol. 38, p. 399, 1926.)

has studied the effect of the constants of the circuit to which the crystal is connected when used as a resonator, but as far as the author is aware, no study has yet been made of the corresponding problem, namely, the effect of the constants of the circuit when the crystal is used as a stabilizer for a vacuum tube driven circuit.

In carring out this work, the crystal has been replaced in the circuits to be studied by its electrical equivalent as given by Van Dyke. It thus forms on of the elements of a coupled system, and the resultant frequency of the driven coupled system has been worked out in terms of that of the equivalent crystal element when uncoupled and oscillating according to one of its normal modes. In making the analysis of the various circuits considered, the method of differential equations rather than complex algebra has been used, since it permits the determination of the condition for oscillation and the calculation of frequency to be made directly from the coefficients of the differential equation. The advantages of this method, which, of course, is well known, seem to be insufficiently appreciated, and a brief discussion of the theory may not be out of place.

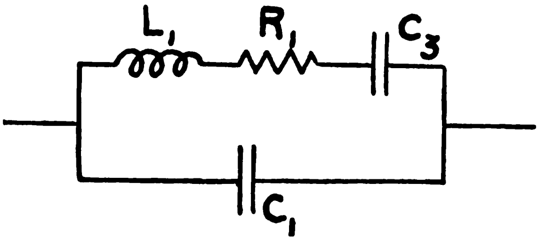


FIG. 1.
Equivalent Network.

Suppose we have any system mechanical or electrical, such that its instantaneous state of motion may be described by a differential equation of the second order, e.g.,

$$\frac{d^2x}{dt^2} + P_1\frac{dx}{dt} + P_2x = 0. \qquad (1)$$

In order that $x = e^{mt}$ may be a solution of (1) it is necessary the auxiliary equation

$$m^2 + P_1m + P_2 = 0. \qquad (2)$$

be satisfied, that is

$$m = \frac{-P_1 \pm \sqrt{P_1^2 - 4P_2}}{2}. \qquad (3)$$

The condition that the system may execute oscillations is that $P_1^2 < 4P_2$. If this condition is satisfied, then the roots of (2) may be written.

$$\left.\begin{array}{l} m_1 = \alpha + j\beta \\ m_2 = \alpha - j\beta \end{array}\right\} \qquad (4)$$

where

$$\alpha = -\frac{P_1}{2} \quad \text{and} \quad \beta = \frac{\sqrt{4P_2 - P_1^2}}{2} + j = \sqrt{-1}.$$

The solution may then be written

$$x = Ae^{\alpha t}\sin\beta t. \qquad (5)$$

The damping factor α is seen to be one-half the coefficient of the first order derivative in (1). In general, P_1 is positive and oscillations die out logarithmically. If, however, the system contains some source of energy or a regenerative device, P_1 may be zero, or even negative. In the former case, oscillations, once started, persist with constant amplitude, and in the latter, built up. The condition then that oscillations may persist in any vacuum tube driven circuit whose instantaneous state may be described by a second order differential equation is that the coefficient of the first order derivative be zero. It is also to be noted by (4) that when this condition has been satisfied, the square of the radian frequency of the system is given by P_2, the coefficient of the absolute term.

Unfortunately, not many tri-ode circuits can be described by a second order differential equation. The method may, however, be extended to cases requiring third and fourth order differential equations for their description. For example, suppose a third order equation is required, e.g.,

$$\frac{d^3x}{dt^3} + P_1\frac{d^2x}{dt^2} + P_2\frac{dx}{dt} + P_3x = 0. \qquad (6)$$

The auxiliary equation is then

$$m^3 + P_1m^2 + P_2m + P_3 = 0. \qquad (7)$$

If the system, thus described, is to be capable of oscillation, two of the roots of (7) must be a pair of conjugate complexes, and the third real. Let them be

$$\left.\begin{aligned} m_1 &= k \\ m_2 &= \alpha + j\beta \\ m_3 &= \alpha - j\beta \end{aligned}\right\} \qquad (8)$$

where α and β are the damping factor and radian frequency respectively, and k the reciprocal of the time constant for the non-oscillatory transient.

The condition that oscillations once started may persist, that is, $\alpha = 0$, may be obtained from the theorem giving the relation between roots and coefficients in an algebraic equation. Thus

$$\left.\begin{aligned} m_1 + m_2 + m_3 &= -P_1 \\ m_1m_2 + m_2m_3 + m_3m_1 &= +P_2 \\ m_1m_2m_3 &= -P_3. \end{aligned}\right\} \qquad (9)$$

Substituting (8) in (9) we have

$$\left.\begin{aligned} k + 2\alpha &= -P_1 \\ 2k + \alpha^2 + \beta^2 &= P_2 \\ k(\alpha^2 + \beta^2) &= -P_3 \end{aligned}\right\} \qquad (10)$$

If $\alpha = 0$, these become

$$\left.\begin{aligned} k &= -P_1 \\ \beta^2 &= P_2 \\ k\beta^2 &= -P_3. \end{aligned}\right\} \qquad (11)$$

Whence

$$\beta^2 = P_2 \quad \text{and} \quad \beta^2 = \frac{P_3}{P_1}. \qquad (12)$$

The condition, then, that $\alpha = 0$, is that these two values of β must be the same; that is

$$P_2 = \frac{P_3}{P_1}. \qquad (13)$$

Thus the condition for undamped oscillations and the expression for the frequency may be obtained from the differential equation without solving it.

For the case of the fourth order differential equation the procedure is similar, and although the conditions are somewhat more complicated, the method is readily workable. Let the differential equation be

$$\frac{d^4x}{dt^4} + P_1\frac{d^3x}{dt^3} + P_2\frac{d^2x}{dt^2} + P_3\frac{dx}{dt} + P_4x = 0 \qquad (14)$$

with its auxiliary equation

$$m^4 + P_1m^3 + P_2m^2 + P_3m + P_4 = 0. \qquad (15)$$

The system which this equation describes may be either simply or doubly periodic. In the former case, (15) has two real and one pair of conjugate complex roots, and in the latter, two pairs of conjugate complex roots. For the doubly periodic case, the roots may be written

$$\left.\begin{aligned} m_1 &= \alpha_1 + j\beta_1 \qquad & m_3 &= \alpha_2 + j\beta_2 \\ m_2 &= \alpha_1 - j\beta_1 \qquad & m_4 &= \alpha_2 - j\beta_2 \end{aligned}\right\} \qquad (16)$$

where α_1, α_2 and β_1, β_2 are the damping factors and radian frequencies respectively, for the resultant oscillations.

Again making use of the relation between roots and coefficients we have

$$\left.\begin{aligned} 2(\alpha_1 + \alpha_2) &= -P_1 \\ \alpha_1^2 + \beta_1^2 + 4\alpha_1\alpha_2 + \alpha_2^2 + \beta_2^2 &= P_2 \\ 2\alpha_1(\alpha_2^2 + \beta_2^2) + 2\alpha_2(\alpha_1^2 + \beta_1^2) &= -P_3 \\ (\alpha_1^2 + \beta_1^2)(\alpha_2^2 + \beta_2^2) &= P_4. \end{aligned}\right\} \qquad (17)$$

The imaginary terms drop out, since the coefficients of (15) are all real. We seek now the conditions that one of the damping factors, e.g., α_1, may be zero. Putting $\alpha_1 = 0$ in (17) α and β_2 may be eliminated, and there results

$$\beta_1^2 = \frac{P_3}{P_1} \quad \text{and} \quad \beta_1^2 = \frac{P_2 \pm \sqrt{P_2^2 - 4P_4}}{2}. \qquad (18)$$

The conditions for undamped oscillations is then either

$$\left.\begin{aligned} \frac{P_3}{P_1} &= \frac{P_2 + \sqrt{P_2^2 - 4P_4}}{2} \\ \text{or} \qquad & \\ \frac{P_3}{P_1} &= \frac{P_2 - \sqrt{P_2^2 - 4P_4}}{2}. \end{aligned}\right\} \qquad (19)$$

Since equations (17) are symmetrical with respect to the α's and β's, the same result would have been obtained had we sought the condition that $\alpha_2 = 0$. It may be shown, however, that in (19) the plus sign gives the condition for one damping factor zero, and the minus sign that for the other zero.

In stabilizing a vacuum tube driven circuit, the crystal may be connected either across the grid and filament of the tube or across the grid and plate. In the former case, the internal capacity between the plate and grid furnishes the necessary feed back coupling, and in the latter, the grid-filament capacity serves this purpose. In this report, the solution will be given for these two cases using in each a tuned resonance circuit in series with the plate. The simplified circuits of Pierce (*) may be discussed as special cases.

Crystal Between Grid and Plate.

I. *Tuned Plate Circuit.* — The circuit diagram for this case in shown in figure 2, in which L_1, R_1, C_3 represent the equivalent series elements of the crystal as shown in figure 1, while C is the sum of the inter-electrode capacitance between plate and grid of the tube and C_1 of the crystal. The simplified diagram is shown in figure 3, where $C_2 = C_2 + C_f$. In setting up the Kirchhoff equations, the d.c. grid current has been neglected and a linear static tube characteristic has been assumed. With these simplifications, we have

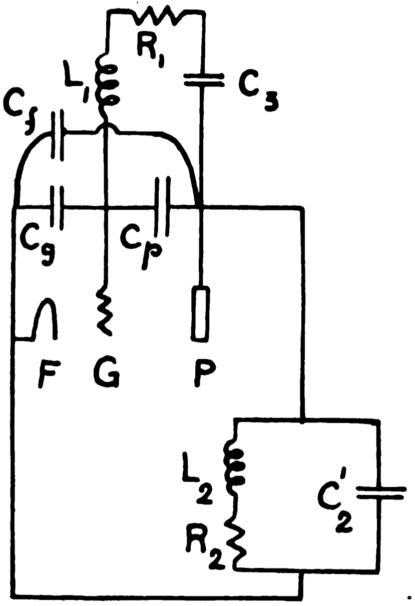


FIG. 2
Network for Crystal Between Grid and Plate.

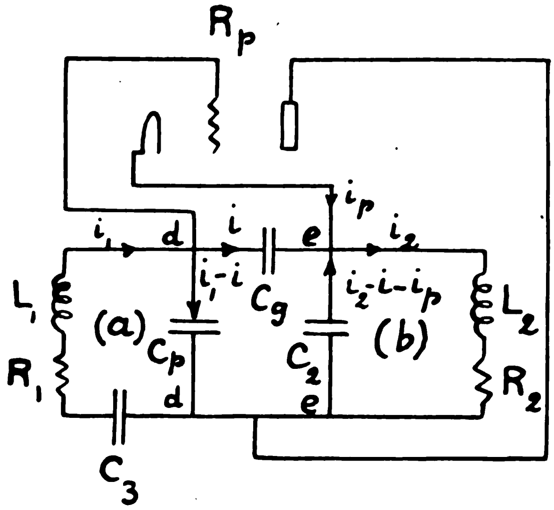


FIG. 3.
Simplified Diagram for figure 2.

$$L_1 \frac{di_1}{dt} + R_1 i_1 + \frac{1}{C_3}\int i_1 dt + \frac{1}{C_p}\int (i_1 - i)\, dt = 0 \qquad (20)$$

$$L_2 \frac{di_2}{dt} + R_2 i_2 + \frac{1}{C_2}\int (i_2 - i - i_p)\, dt = 0. \qquad (21)$$

$$\frac{1}{C_g}\int i dt - \frac{1}{C_2}\int (i_2 - i - i_p)\, dt - \frac{1}{C_p}\int (i_1 - i)\, dt = 0 \qquad (22)$$

$$i_p = \frac{1}{R_n}(e_p + \mu e_g) \qquad (23)$$

where

$$e_p = \frac{1}{C_2}\int (i_2 - i - i_p)\, dt; \quad e_g = \frac{1}{C_g}\int i dt.$$

Differentiating and combining, these become

$$L_1 \frac{d^2 i_1}{dt^2} + R_1 \frac{di_1}{dt} + \left(\frac{1}{C_3} + \frac{1}{C_p}\right) i_1 - \frac{1}{C_p} i = 0 \qquad (24)$$

$$L_2 \frac{d^2 i_2}{dt^2} + R_2 \frac{di_2}{dt} + \frac{1}{C_2}(i_2 - i - i_p) = 0 \qquad (25)$$

$$i = \frac{C_0}{C_p} i_1 + \frac{C_0}{C_2}(i_2 - i_p) \qquad (26)$$

$$\frac{di_p}{dt} = \frac{1}{R_r}\left[\frac{1}{C_2}(i_2 - i - i_p) + \frac{\mu}{C_g} i\right] \qquad (27)$$

where

$$\frac{1}{C_0} = \frac{1}{C_p} + \frac{1}{C_g} + \frac{1}{C_2}.$$

Substituting (26) in (24), (25), and (27) respectively, we have

$$i_2 - i_p = L_1 C_m \frac{d^2 i_1}{dt^2} + R_1 C_m \frac{di_1}{dt} + \frac{C_m i_1}{C_a} \qquad (28)$$

$$L_2 \frac{d^2 i_2}{dt^2} + R_2 \frac{di_2}{dt} + \frac{1}{C_b}(i_2 - i_p) - \frac{1}{C_m} i_1 = 0 \qquad (29)$$

$$\frac{di_p}{dt} = \frac{1}{R_p}\left[\frac{1}{C'_b}(i_2 - i_p) - \frac{1}{C'_m} i_1\right] \qquad (30)$$

where

$$\frac{1}{C_m} = \frac{C_0}{C_2 C_p}; \quad \frac{1}{C'_b} = \frac{1}{C_b} + \mu \frac{C_0}{C_2 C_g}; \quad \frac{1}{C'_m} = \frac{1}{C_m} - \mu \frac{C_0}{C_p C_g}$$

The total capacitance of the primary circuit between the points *dd* is designated by C_a, and that of the secondary between points ee, by C_b.

(*) PIERCE, G. W., Piezo-Electric Crystal Resonators and Crystal Oscillators Applied to Precision Calibration of Wave Meters. (*Proc. Am. Acad.*, vol. 59, p. 81, 1923.)

Substituting (28) in (29) and (30) respectively, there results

$$\left.\begin{aligned} & L_2\frac{d^2i_2}{dt^2}+R_2\frac{di_2}{dt}+\frac{L_1C_m}{C_b}\frac{d^2i_1}{dt^2}+\frac{R_1C_m}{C_b}\frac{di_1}{dt} \\ & \qquad +\left(\frac{C_m}{C_aC_b}-\frac{1}{C_m}\right)+i_1=0 \end{aligned}\right\} \qquad (31)$$

$$\frac{di_p}{dt}=\frac{L_1C_m}{R_pC_b'}\frac{d^2i_1}{dt^2}+\frac{R_1C_m}{R_pC_b'}\frac{di_1}{dt}+\frac{1}{R_p}\left(\frac{C_m}{C_aC_b'}-\frac{1}{C_m'}\right)i_1 \qquad (32)$$

Differentiating (28) and substituting (32), we have

$$\left.\begin{aligned} \frac{di_2}{dt} &= L_1C_m\frac{d^3i_1}{dt^3}+\left(R_1C_m+\frac{L_1C_m}{R_pC_b'}\right)\frac{d^2i_1}{dt^2} \\ & \quad +\left(\frac{C_m}{C_a}+\frac{R_1C_m}{R_pC_b'}\right)\frac{di_1}{dt}+\frac{1}{R_p}\left(\frac{C_m}{C_aC_b'}\frac{1}{C_m'}\right)i_1. \end{aligned}\right\} \qquad (33)$$

Substituting (33) and its derivative in (31) the following fourth order differential equation results :

$$\frac{d^4i_1}{dt^4}+P_1\frac{d^3i_1}{dt^3}+P_2\frac{d^2i_1}{dt^2}+P_3\frac{di_1}{dt}+P+i_1=0. \qquad (34)$$

in which

$$\left.\begin{aligned} P_1 &= \frac{R_1}{L_1}+\frac{R_2}{L_2}+\frac{1}{R_pC_b'} \\ P_2 &= \frac{1}{L_1C_a}+\frac{R_1R_2}{L_1L_2}+\frac{1}{L_2C_b}+\frac{1}{R_p}\left(\frac{R_1}{L_1}+\frac{R_2}{L_2}\right)\frac{1}{C_b'} \\ P_3 &= \frac{R^2}{L_1L_2C_a}+\frac{R_1}{L_1L_2C_b} \\ & \qquad +\frac{1}{R_p}\left(\frac{1}{L_1C_aC_b'}+\frac{R_1R_2}{L_1L_2C_b'}-\frac{1}{L_1C_mC_m'}\right) \\ P_4 &= \frac{1}{L_1L_2C_aC_b}-\frac{1}{L_1L_2C_m^2}+\frac{R_2}{R_p}\left(\frac{1}{L_1L_2C_aC_b}-\frac{1}{L_1L_2C_mC_m'}\right). \end{aligned}\right\} \qquad (35)$$

Introducing now the uncoupled damping factors α_a and α_b; the uncoupled, undamped frequencies β_a and β_b and the coupling coefficient τ, defined as follows :

$$\alpha_a=\frac{R_1}{2L_1} \qquad \beta_a^2=\frac{1}{L_1C_a} \qquad \tau^2=\frac{\frac{1}{C_m^2}}{\frac{1}{C_a}\cdot\frac{1}{C_b}}=\frac{C_aC_b}{C_m^2}$$

$$\alpha_b=\frac{R_2}{2L_2} \qquad \beta_b=\frac{1}{L_2C_b}$$

the coefficients of (35) become

$$\left.\begin{aligned} P_1 &= 2(\alpha_a+\alpha_b)+\frac{1}{R_pC_b'} \\ P_2 &= \beta_a^2+4\alpha_a\alpha_b+\beta_b^2+\frac{1}{R_p}(\alpha_a+\alpha_b)\frac{2}{C_b'} \\ P_3 &= 2(\alpha_b\beta_a^2+\alpha_a\beta_b^2) \\ & \qquad +\frac{1}{R_p}\left[(\beta_a^2+4\alpha_a\alpha_b)\frac{1}{C_b'}-\frac{1}{L_1C_mC_m'}\right] \\ P_4 &= \beta_a^2\beta_b^2\left[1-\tau^2+\frac{R^2}{R_p}\left(\frac{C_b}{C_b'}-\frac{C_m}{C_m'}\tau^2\right)\right]. \end{aligned}\right\} \qquad (36)$$

Depending upon the coefficients P_1 ..... P_4, the solution of (34) may represent four exponentally damped transients, two such transients and a periodic function, or a doubly periodic function. In the circuits with which we are generally concerned in radio work, the last of these possibilities usually obtains. Neglecting for the moment the effect of the tube, the normal modes of oscillation of the coupled circuits *a* and *b*, figure 3, consist of two currents in each circuit with frequencies and damping factors β_1 and α_1, β_2 and α_2 respectively. The components of each current in each circuit are for one, nearly in phase, and for the other, nearly opposite in phase. By suitably connecting the tube to the circuit, one of the normal modes of oscillation, β_1, for example, may supply voltages to grid and plate respectively nearly opposite in phase, and regeneration will occur for this frequency, while for the other frequency β_2, the grid and plate voltage are nearly in phase and absorption of energy by the tube rapidly damps this oscillation out. However, by an appropriate change in the connections, the situation may be reversed and regeneration occur for the frequency β_2 and absorption for β_1. Because of these phase relations between the primary and secondary currents for the two normal modes of oscillation, it is not possible to have regeneration of both frequencies at the same time with a single tube. In the case of the crystal stabilized oscillators here studied, the system oscillates according to one of its normal modes when the crystal is connected between grid and plate, and to the other, when connected between grid and filament.

The action of the tube in driving such a circuit may be roughly regarded as neutralizing the resistance of the circuit for one of the frequencies, that is, in making one of the damping factors effectively zero, and at the same time increasing the other damping factor. In general, resistance neutralization is incomplete in that the frequency of the resulting oscillations is determined not by the inductances, capacitances, and degree of coupling of the circuits alone, but by the resistances of the two circuits and the electrical constants of the tube as well. The expression for the resultant frequency is given by equation (18), where the P's of equations (36) are given such values that the condition for oscillation, equation (19), is satisfied.

II. *Inductance Loaded Circuit.* — This may be regarded as a special case of the circuit just discussed in which C_2 is reduced to C_f, the capacitance between plate and filament of the tube. The circuit is still doubly periodic.

III. *Resistance Loaded Circuit.* — This is also a special case of the above in which, in addition to putting C_2 equal to C_f, L_2 is made zero. Thus, multiplying equation (34) by L_2 and then placing $L_2 = 0$ there results

$$\frac{d^3 i_1}{dt^3} + P_1 \frac{d^2 i_1}{dt^2} + P_2 \frac{di_1}{dt} + P_3 i_1 = 0. \qquad (37)$$

in which

$$\left.\begin{aligned} P_1 &= \frac{R_1}{L_1} + \frac{1}{R_2 C_b} + \frac{4}{R_p C'_b} \\ P_2 &= \frac{1}{L_1 C_a} + \frac{R_1}{R_2 L_1 C'_b} + \frac{R_1}{R_p L_1 C'_b} \\ P_3 &= \frac{1}{R_2 L_1 C_a C_b} - \frac{1}{R_2 L_1 C_m^2} + \frac{1}{R_p}\left(\frac{1}{L_1 C_a C'_b} - \frac{1}{L_1 C_m C'_m}\right). \end{aligned}\right\} \qquad (38)$$

Introducing the uncoupled damping factors and frequency of equation (36), equations (38) become

$$\left.\begin{aligned} P_1 &= 2\alpha_a + \frac{1}{R_2 C_b} + \frac{1}{R_p C'_b} \\ P_2 &= \omega_a^2 + \frac{2\alpha_a}{R_2 C_b} + \frac{2\alpha_a}{R_p C'_b} \\ P_3 &= \frac{\omega_a^2}{R_2 C_b} - \frac{1}{R_2 L_1 C_m^2} + \frac{1}{R_p}\left(\frac{\omega_a^2}{C'_b} - \frac{1}{L_1 C_m C'_m}\right). \end{aligned}\right\} \qquad (39)$$

This circuit is singly periodic and its frequen- is given by equation (12) when the condition for oscillation, equation (13), has been satisfied.

Crystal Between Grid and Filament

IV. *Tuned Plate Circuit.* — The circuit for this case is shown in figure 4 and the simplified diagram in figure 5, where C_2 is again $C_2 + C_f$. C_p is here the coupling condenser instead of C_g.

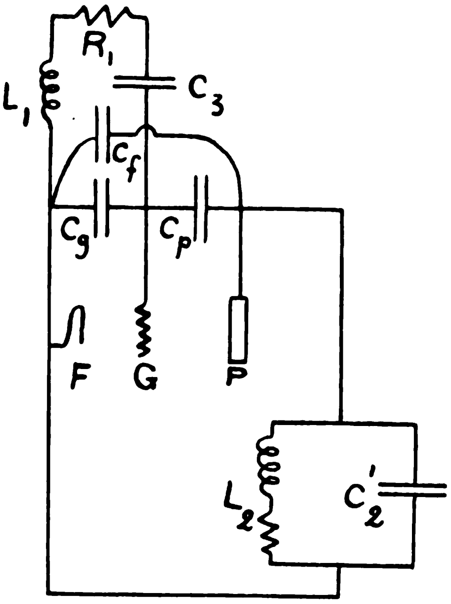


FIG. 4.
Network for Crystal Between Grid and Plate.

Writing the Kirchhoff relations, we have

$$L_1 \frac{di_1}{dt} + R_1 i_1 + \frac{1}{C_3}\int i\,dt + \frac{1}{C_g}\int (i_1 - i)\,dt = 0 \qquad (40)$$

$$L_2 \frac{di_2}{dt} + R_2 i_2 + \frac{1}{C_2}\int (i_2 + i_p - i)\,dt = 0 \qquad (41)$$

$$\frac{1}{C_p}\int i\,dt - \frac{1}{C_2}\int (i_2 + i_p - i)\,dt - \frac{1}{C_g}\int (i_1 - i)\,dt = 0 \qquad (42)$$

$$i_p = \frac{1}{R_p}(e_p + \mu e_g) \qquad (43)$$

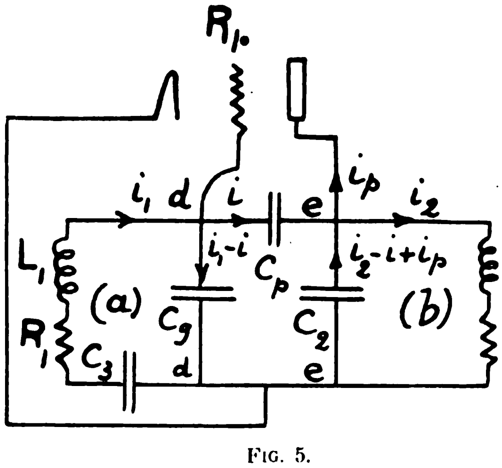


FIG. 5.
Simplified Diagram for figure 4.

where

$$e_p = -\frac{1}{C_2}\int (i_2 + i_p - i)\, dt$$

$$e_g = \frac{1}{C_g}\int (i_1 - i)\, dt.$$

These equations differ only in minor details from equations (20) to (23), and the method of elimination is strictly analogous and will not be repeated. When the process has been carried out, there again results the fourth order differential equation.

$$\frac{d^4 i_1}{dt^4} + P_1 \frac{d^3 i_1}{dt^3} + P_2 \frac{d^2 i_1}{dt^2} + P_3 \frac{di_1}{dt} + P_4 i_1 = 0 \qquad (44)$$

in which

$$\left.\begin{aligned} P_1 &= \frac{R_1}{L_1} + \frac{R_2}{L_2} + \frac{1}{C_p C_b''} \\ P_2 &= \frac{1}{L_1 C_a} + \frac{R_1 R_2}{L_1 L_2} + \frac{1}{L_2 C_b} + \frac{1}{R_p}\left(\frac{R_1}{L_1} + \frac{R_2}{L_2}\right)\frac{1}{C_b''} \\ P_3 &= \frac{R_2}{L_1 L_2 C_a} + \frac{R_1}{L_1 L_2 C_b} \\ &\qquad + \frac{1}{R_p}\left(\frac{1}{L_1 C_a C_b''} + \frac{R_1 R_2}{L_1 L_2 C_b''} - \frac{1}{L_1 C_m C_m''}\right) \\ P_4 &= \frac{1}{L_1 L_2 C_a C_b} - \frac{1}{L_1 L_2 C_m^2} + \frac{R_2}{R_p}\left(\frac{1}{L_1 L_2 C_a C_b''} - \frac{1}{L_1 L_2 C_m C_m''}\right) \end{aligned}\right\} \qquad (45)$$

Substituting uncoupled frequencies and damping factors they become

$$\left.\begin{aligned} P_1 &= 2(\alpha_a + \alpha_b) + \frac{1}{R_p C_b''} \\ P_2 &= \beta_a^2 + 4\alpha_a\alpha_b + \beta_b^2 + \frac{1}{R_p}(\alpha_a + \alpha_b)\frac{2}{C_b''} \\ P_3 &= 2(\alpha_b\beta_a^2 + \alpha_a\beta_b^2) \\ &\qquad + \frac{1}{R_p}\left[(\beta_a^2 + 4\alpha_a\alpha_b)\frac{1}{C_b''} - \frac{1}{L_1 C_m C_m''}\right] \\ P_4 &= \beta_a^2\beta_b^2\left[1 - \tau^2 + \frac{R_2}{R_p}\left(\frac{C_b}{C_b''} - \frac{C_m}{C_m''}\tau^2\right)\right] \end{aligned}\right\} \qquad (46)$$

where

$$\frac{1}{C_m} = \frac{C_0}{C_2 C_g}; \quad \frac{1}{C_m''} = \frac{1}{C_m} + \frac{\mu}{C_d}; \quad \frac{1}{C_b''} = \frac{1}{C_b} + \frac{\mu}{C_m}$$

C_d is the capacitance between the points dd of figure 5. The other quantities have the same meaning as in the case I.

V. *Inductance Loaded Circuit.* — As in case II, the coefficients P_1 ..... P_4 are obtained by putting $C_2 = C_f$. The circuit is doubly periodic.

VI. *Resistance Loaded Circuit.* — As in case III, multiply equation (44) by L_2, put $L_2 = 0$, and there results

$$\frac{d^3 i_1}{dt^3} + P_1 \frac{d^2 i_1}{dt^2} + P_2 \frac{di_1}{dt} + P_3 i_1 = 0, \qquad (47)$$

where

$$\left.\begin{aligned} P_1 &= 2\alpha_a + \frac{1}{R_2 C_b} + \frac{1}{R_2 C_b''} \\ P_2 &= \beta_a^2 + \frac{2\alpha_a}{R_2 C_b} + \frac{2\alpha_a}{R_p C_b''} \\ P_3 &= \frac{\beta_a}{R_2 C_b} - \frac{1}{R_2 L_1 C_m^2} + \frac{1}{R_p}\left(\frac{\beta_a^2}{C_b''} - \frac{1}{L_1 C_m C_m''}\right). \end{aligned}\right\} \qquad (48)$$

Numerical Calculations.

As pointed out above, the expression for the frequency of the vacuum tube driven circuit, when doubly periodic, is given by

$$\beta^2 = \frac{P_2 \pm \sqrt{P_2^2 - 4P_4}}{2} \qquad (49)$$

where the coefficients of the fourth order differential equation have such values that the condition for oscillation, i.e.,

$$\frac{P_2 \pm \sqrt{P_2^2 - 4P_4}}{2} = \frac{P_3}{P_1} \qquad (50)$$

is satisfied, and for the singly periodic circuit

$$\beta^2 = P_2 \qquad (51)$$

where

$$P_2 = \frac{P_3}{P_1}. \qquad (52)$$

In satisfying the condition for oscillation for any given values of the uncoupled frequencies β_a and β_b, R_p is a variable parameter. R_p is, in reality, the reciprocal of the slope of the static characteristic of the tube as given by equation (23). Since, however, the actual characteristic of the tube is not linear but is curved, R_p has different values for various points on the curve. Moreover, for cyclic variations in grid potential, R_p has different values throughout the cycle and it must therefore, when used in numerical calculations, be thought of as a sort of average value taken over the cycle. The greater the limits of grid potential variations, the freaker is R_p. It is thus a purely fictitious quantity, to which it is impossible to give a definite physical meaning, but which serves a useful purpose. In general, the larger the value reached by R_p, the more vigorously is the circuit oscillating.

The direct method for computing the frequency of the system would be to substitute in equation (50) any pair of values for the uncoupled frequencies β_a and β_b and solve for R_p. This value of R_p, when substituted in equation (49), would then give the frequency of the driven system for these values of β_a and β_b. Unfortunately, equation (50) is too complicated a function of R_p to make this procedure possible, and a graphical method was employed. The right and left hand members of equation (50) were plotted as a function of R_p for a series of values of β_a and β_b. The intersection of these curves then gave the value of β^2 for this combination of uncoupled frequencies.

To simplify the computations and make them more general application, relative frequencies rather than actual frequencies of any particular crystal were used. Dividing equations (49) and (50) by β_a^2 we have

$$\left(\frac{\beta^2}{\beta_a}\right) = \frac{P_2}{\beta_a^2} \pm \sqrt{\left(\frac{P_2}{\beta_a^2}\right)^2 - \frac{4P_4}{\beta_a^4}}. \qquad (53)$$

Equation (53) gives the ratio of the driven frequency of any crystal to its undriven value in terms of the ratio of the frequency of the plate circuit to the undriven frequency of the crystal.

The computations were carried out for a crystal having the dimensions shown in Table I. The measured value of its driven fundamental frequency for « thickness » oscillations was 451.53 kc.

TABLE I. — Tuned Plate Circuit.

Dimensions of crystal.	Electrical constants of crystal.	Tube constants. (UX 201 *a*).
—	—	—
Length = 3.328 cm.	L_1 = 3.656 *h*	G-F cap. = 5.8 μμ*f*
Breadth = 2.750 cm.	R_1 = 9035.5 Ω	G-P cap. = 10.1 »
Thickness = .6361 cm.	C_1 = 5.7551 μμ*f*	P-F cap. = 6.1 »
	C_3 = 0.03165 »	Amp. fact. = 8.5 »

Coupling coefficients.

Crystal between grid and plate (τ^2) = $1.0356.10^{-6}$.
Crystal between grid and filament (τ^2) = $3.1355.10^{-6}$.

$\frac{\beta_b}{\beta_a}$	R_p	$\frac{\beta}{\beta_a}$ Crystal between grid and plate.	$\frac{\beta}{\beta_a}$ Crystal between grid and filament.	$\frac{\beta}{\beta_a}$ Natural frequencies undamped.
—	—	—	—	—
.94	47000	1.0000121	—	1.0000035
.96	72500	1.0000122	—	1.0000060
.98	144000	1.0000143	—	1.0000120
.99	260000	1.0000262	—	1.0000251
.995	370000	1.0000540	—	1.0000523
1.005	455000	—	.999847	.999846
1.01	394000	—	.999922	.999921
1.02	238000	—	.999963	.999959
1.04	126000	—	.999986	.999979
1.06	87000	—	.999996	.999986

In this table, the column marked R_p gives the effective resistance of the tube for stable oscillations, that is the value for which one of the damping factors of the driven coupled circuit is zero. It is to be noted that as resonance is approached from either side, R_p increases in magnitude corresponding to greater amplitudes of oscillation. Before resonance is reached however, the condition for oscillation ceases to be satisfied by any value of R_p no matter how great. The gradual increase in amplitude of oscillation as the plate circuit is brought into resonance and the sudden break are well known experimentally. Attention should be drawn to the fact that the coupling between the two circuits is considerably closer when the crystal is connected between grid and filament then when between grid and plate, which accounts for the larger amplitude of oscillation and greater stability for this connection. The last column gives the computed undamped frequencies for the system, using in each case the appropriate coupling coefficient. The formula for computting them is obtained by putting $R_1 = R_2 = R_p = \infty$ in equation (34) or (44) which become identical under these conditions. In carring out these computations, it is found that with the above circuits constants for ratios of $\frac{\beta_b}{\beta_a}$ less than unity, the condition for oscillation can be satisfied only when the plus sign of equation (53) is used and for ratios greater than unity with the minus sign only.

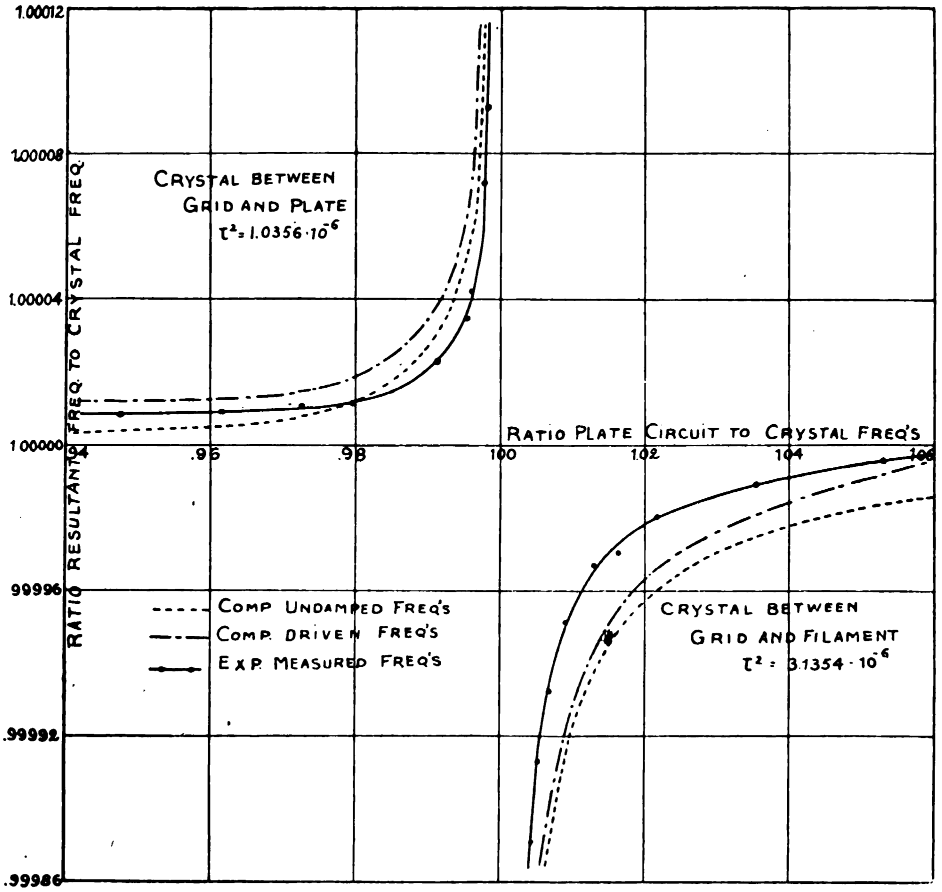


FIG. 6.
Variation of Driven Frequency with Plate Circuit Frequency.

These results are shown in figure 6, in which the dash-dot curve shows the frequency of the vacuum tube driven crystal controlled oscillator as a function of the relative frequency of the plate circuit, while the dot-dot curve shows the natural frequencies of the same system if it were without resistance. It is seen that the effect of driving is to increase somewhat the frequency of the system for both connections of the crystal, and that this effect is greater the farther the circuits are off resonance. The experimentally measured frequencies are shown in the full line curve. It was found impossible to satisfy the condition for oscillation using the value of R_1 obtained by Van Dyke's formula, even though R_2 were as small as 0.3 ohm, the value used in the experimental work. A series of calculations was carried through, using successively smaller and smaller fractions of R_1, and in the above curves, R_1 was put equal to one-tenth that given by Van Dyke's formula. It will be noted that the experimentally measured curves show a somewhat sharper resonance effect than the computed ones, and if a still smaller value of R_1 had been used the check would have been better. Because of the uncertainty in the values of some of the other constants of the circuit, this can hardly be considered a method for measuring the effective resistance of a crystal, but indicates that the values given by Van Dyke's formula are probably too large.

Inductance Loaded Circuit. — Calculations for this case are not given since, as pointed out above, this is a special case of the tuned plate circuit in which C_2 is simply the capacitance between plate and filament of the tube.

Resistance Loaded Circuit. — Introducing relative frequencies in equations (51) and (52), we have

$$\left(\frac{\beta}{\beta_a}\right)^2 = \frac{P_2}{\beta_a^2} = \frac{\frac{P_3}{\beta_a^2}}{P_1}; \qquad (53)$$

Substituting the values for P_1 ..... P_3 of equations (38) and (48) in (53), it was found that the condition for oscillation can be satisfied only for the case of the crystal between grid and plate, and for this the following results were computed for different values of R_2 the load, or series plate resistance.

TABLE II

R_2	$\frac{\beta}{\beta_a}$	R_p
10000	1.00000536	6240
20000	1 00000503	6000
30000	1.00000096	5900
50000	1.00000048	5750
100000	1.00000042	5700

In this case it is to be noted that the crystal is forced from its natural frequency, at most, by only five parts in a million, and that the variation in frequency is very much less than in the case of the tuned circuit load. The values of R_p, however, are relatively small, indicating that the oscillations are weak, and the fact that they decrease as R_2 is increased indicated that the oscillations become weaker as the load is increased.

Experimental Checks.

To test the theory as given above, two crystal controlled oscillators of the various types there discussed were set up, each having its own A and B battery supply, and appropriate precautions were taken to insure a minimum of interaction between them. Each was loosely coupled to a third circuit containing a rectifier and an audio frequency amplifier. Connected to this third circuit was an audio oscillator of continously variable frequency calibrated in terms of a series of standard tuning fork. The crystals under test were ground in pairs so as to give audio frequency while the other was experimented upon. The beat frequency between the crystals was then matched by the audio oscillator. This double heterodyne arrangement is an exceedingly sensitive method for studying problems involving frequency changes, since a variation of one cycle per second in either of the radio frequency circuits gives an audio frequency beats to be held constant to one beat in 10 seconds.

The results for the tuned plate circuit case are shown by the full line curve of figure 6, reference to which has already been made. For the resistance loaded circuit the variations of frequency with load resistance were so small as to be barely within the limit of error of measurement, i.e., one or two parts per million. This checks the results of Table II, where maximum changes of only 5 parts per million were predicted. For standardization purposes, where extreme accuracy is the objective, the resistance loaded circuit is thus much to be preferred. However, this circuit gives much weaker oscillations and will in general require an extra stage of amplification. Moroever, a crystal must be a very « good oscillator » to be used at all in this circuit. Out of some twenty crystals used in connection with this work, only three would function with this arrangement.

An experimental study was made of the effect of varying the resistance R_2 for the two cases of tuned plate circuit oscillators, and the results are shown in figure 7, where the frequency of the driven system is shown in terms of the uncoupled frequency of the plate circuit. These results indicate that as R_2 is increased the separation between coupled frequencies is increased and that the sharpness of resonance is decreased. The range of plate circuit frequency over which oscillations occur is decreased by increasing load.

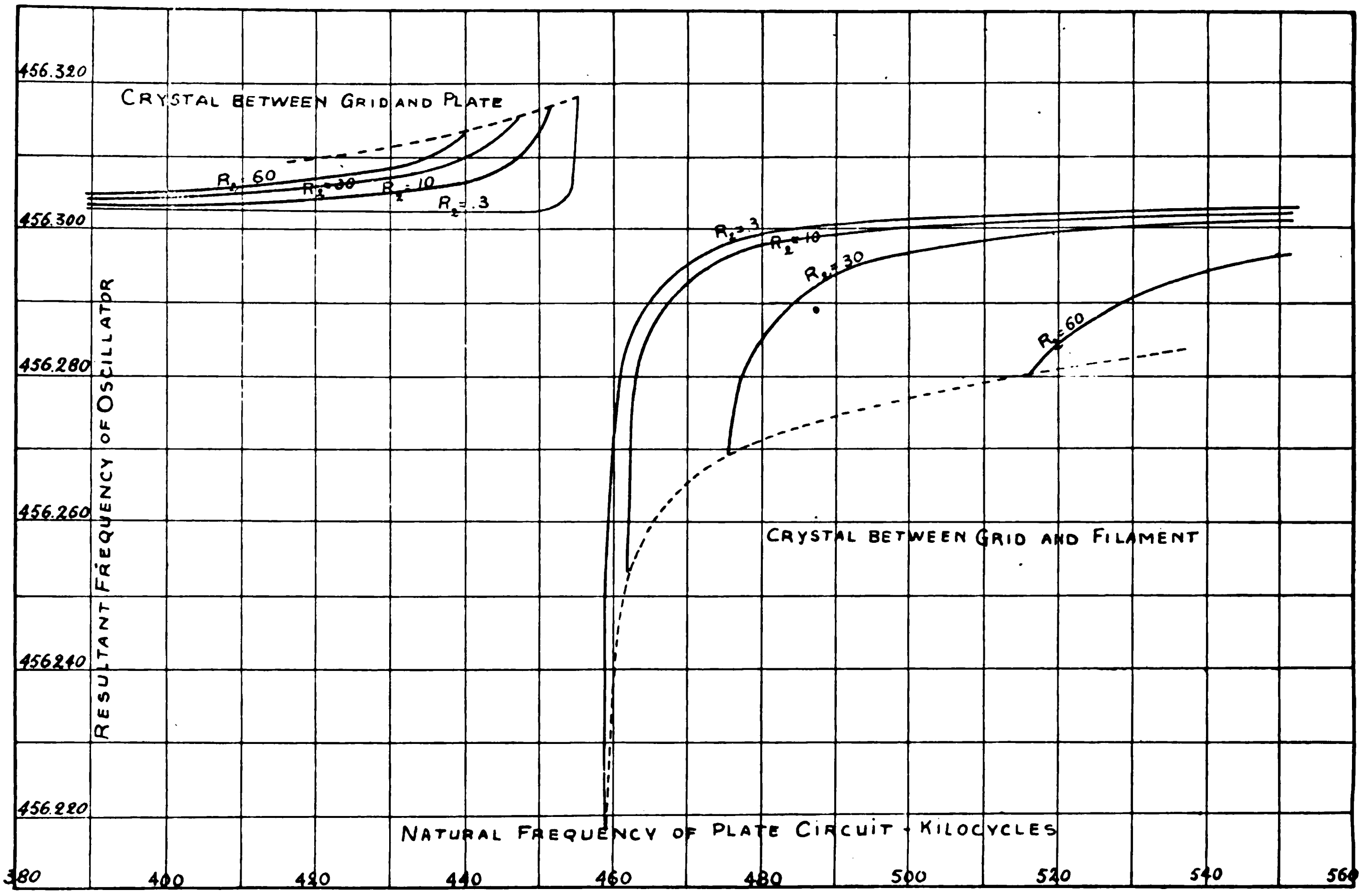


Fig. 7.
Variation of Driven Frequency with Resistance of Tuned Plate Circuit.

Conclusions.

A quartz crystal oscillator, when used to stabilize a vacuum tube driven circuit, does not oscillate at a frequency determined by its elastic and piezo-electric properties alone, but becomes part of a coupled system, and the actual resultant frequency is influenced by the degree of coupling of the two systems and the values of the constants of the entire circuit, including those of the driving device in the case of continuous oscillations. In doubly periodic vacuum tube driven circuits, one of the normal modes of oscillation is excited when the crystal is connected between grid and plate, and the other when connected between grid and filament. Although the oscillations are more powerful when the frequency of the plate circuit is close to that of the crystal are greater. For purposes of accurate frequency standard maintenance, resistance loaded circuit is much to be preferred, and when a crystal has been standardized it must always be used in exactly the same circuit and under exactly the same conditions as when the standardization was made. It is desirable from this standpoint to preserve not merely the crystal, but the entire permanently assembled.

In conclusion, the author wishes to express his indebtedness to the America Association for the Advancement of Science for a grant for the purchase of equipment, to Dr. A. Hoyt Taylor of the Naval Research Laboratory for a supply of accurately ground quartz plates, and to Mr. J. C. Cavender for carring out the experimental measurements.

University of Wisconsin, Madison, Wisconsin,
July 30, 1928.

SUMMARY.

The mathematical theory for the quartz piezoelectric stabilized, vacuum tube driven oscillator is given for the following cases : tuned plate circuit, inductance loaded and resistance loaded triode with the crystal between grid and plate, and also between grid and filament for each case. The condition for oscillations and the exact expression for the frequency of the driven circuit in terms of uncoupled frequencies, damping factors, coupling coefficient, tube constants, etc., is given. In the analysis of the oscillator the equivalent network for the crystal given by Van Dyke has been used. A discussion of the general method by which conditions for oscillation and expressions for the driven frequency of an oscillator may be obtained from the coefficients of differential equations up to the fourth order is included.

PIEZO-ELECTRIC QUARTZ OSCILLATOR WITH SINGLE FREQUENCY.

by ISAAC KOGA.
(The Electrical Research Laboratory of Tokyo City.)

It is sometimes desirable that a quartz-oscillator should oscillate only at a single frequency, and at the same time very intesely. This paper gives a procedure to get such an oscillator.

Take the optical axis of a single crystal of quartz as z, one of the electrical axis as x, and the direction perpendicular to both axes as y, such that the co-ordinate system is right-handed or left-handed, corresponding respectively to the right and left-handed quartz crystal. The relations between components of strain and applied electrical field are :

$$\left.\begin{array}{ll} -e_{xx} = -d\,E_x & -e_{zx} = -d'E_y \\ -e_{yy} = \;\; d\,E_x & -e_{xy} = 2d\,E_y \\ -e_{yz} = \;\; d'E_x & \end{array}\right\} \qquad (1)$$

where

E_x and E_y : x — and y — components of the applied electrical field,

e_{xx}, etc. : components of strain produced,

d and d' : piezo-electric moduli, whose numerical values are

$$d = 6.45 \times 10^{-8}, \qquad d' = 1.45 \times 10^{-8} \text{ (*)}.$$

Now that the same state of strain can be expressed referring to some other co-ordinate system, we shall suppose the second system to be connected with the first by the orthogonal scheme

	x	y	z
x'	1	0	0
y'	0	$\cos\theta$	$-\sin\theta$
z'	0	$\sin\theta$	$\cos\theta$

and suppose that the direction of the applied field $E_{y'}$ is in the direction of y' axis, then the effective field to produce the strain is $E_{y'}\cos\theta$, and the components of the strain referred to the new axes are :

$$\left.\begin{array}{rl} -e_{z'x'} & = -(e_{zx}\cos\theta + e_{xy}\sin\theta) \\ & = E_y'\cos\theta\,(-d'\cos\theta + 2d\sin\theta) \\ -e_{x'y'} & = -(-e_{zx}\sin\theta + e_{xy}\cos\theta) \\ & = E_y'\cos\theta\,(d'\sin\theta + 2d\cos\theta) \end{array}\right\} \qquad (2)$$

and all the other components vanish.

(*) *Grätz-Handbuch der Elektrizität u. des Magnetismus*, Bd I, S. 365.

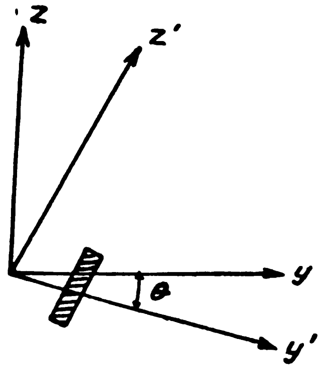
As a special case, when

$$\theta = \text{arc tan}\,\frac{d'}{2d} \doteq 6^\circ 24' \qquad (3)$$

equations (2) reduce to the following.

$$\left.\begin{aligned} -e_{z'x'} &= 0 \\ -e_{x'y'} &= 2d\,E_{y'} \end{aligned}\right\} \qquad (4)$$

According to this equation, only one component of the strain is produced by application of the electric field, so that only one kind of resonance frequency can be obtained in case of an alternating electric field.



This reasoning may not be rigorously true in the state of high frequency vibration as in the statical case, because the quartz crystal is perhaps an aeolotropic elastic body. But quartz oscillators actually cut perpendicular to the y' axis can not oscillate with other than one frequency; the intensity of oscillation is very intense and the failure rarely happens.

The angle of inclination θ can be made easily with the error lying between ± 30′, but practically this value need not be so exact due perhaps to a considerable small value of the piezo-electric modulus at a small value of θ given by the first equation of (2).

The frequency is experimentally given as :

$$\lambda = 150 \times t$$

where

λ : wave length in metres of the oscillating current corresponding to the frequency of quartz oscillator.

t = thickness of quartz oscillator in mm. in the direction of y' axis.

A CONVENIENT METHOD FOR REFERRING SECONDARY FREQUENCY STANDARDS TO A STANDARD TIME INTERVAL.

by L. M. HULL and J. K. CLAPP.

1. Introduction. — In recent years the technic of frequency standardization has been refined and improved through the development of oscillating systems which are so nearly invariant that their average frequency is practically independent of the time interval for which the average is determined. Such a system permits the determination of frequency, by counting successive cycles, to a degree of precision which is usually limited only by the patience of the observer. Extensive use of this « absolute » method of frequency measurement has suggested the concept of the earth's rotational frequency, or a time interval defined thereby, as a fundamental standard for frequencies of all magnitudes.

Practical methods for maintaining various types of oscillators as the intermediate links between the desired frequency and a standard time interval have already been the described in the literature. It is the purpose of the present paper to call attention to an application of the same general principle to a specific problem of laboratory calibration. The results described have a general significance insofar as they relate to the establishment of a harmonic series of standard frequencies.

At the present time there are approximately 600 radio broadcasting stations operating more or less continuously in the United States. The transmitters of these stations have an irregular geographical distribution and to each transmitter is assigned as a carrier one of the 96 decimal frequencies between and including the limits 1,500 and 550 kilocycles. The universal problem of interference is not solved by accurate maintenance of the carrier frequencies on their assigned values, but such maintenance is obviously a primary essential. Although piezoelectric oscillators or their equivalent will ultimately be incorporated as integral frequency control elements of all broadcast transmitters, such arrangements are not now in general use. Small portable piezo-oscillators are widely employed in the broadcasting stations as comparison standards, by means of which their carrier frequencies may be occasionally corrected. The problem of accurate adjustment of quantities of these comparison standards to the even decimal frequencies employed by these stations has suggested the calibration method which we are to describe.

2. Experimental Method. — The general technic of « direct » calibration from a single-frequency source, which in turn is compared with the earth's rotational frequency, is based upon an assumption which may be stated as follows: if oscillations of constant periodicity occur in two independent systems and either system be so adjusted that the fundamental constituent of its oscillation coincides constantly with a harmonic constituent of the oscillation in the other system, then the fundamental frequency of either system is uniquely determined in terms of the other. The propriety of this assumption will not be discussed here although other investigators have given attention to specific phases of it, as for instance by examining the validity of identifying with integral harmonic ratios the various emission frequencies from a multivibrator (1) (*). If, therefore, our fundamental oscillation occurs at a low frequency and is associated with a substantial series of real harmonics, the physical comparison of an unknown frequency with the frequency of one of these harmonics is considered to be an absolute comparison with the fundamental. Since the ultimate standard of frequency is very low indeed compared with what we normally have to measure, it is customary to employ the intermediate source of oscillations previously mentioned as the basis of the harmonic series from which calibrations are actually made.

An electro-mechanical oscillator such as a tuning fork has been extensively used as an intermediate source. A tube-driven fork can be coupled directly to the counting mechanism, but the fundamental frequency is inconveniently remote from the frequencies at which calibrations are required; also the fork is subject to the familar limitations arising from its damping and its temperature coefficient. The use of a piezoelectric oscillator as the intermediate source has been described in an important paper read before the Washington meeting of U. R. S. I. in October 1927 (2). The quartz oscillator exhibits smaller perturbations under reasonable operating conditions, and permits the establishment of a harmonic series from a fundamental of higher frequency. It requires, however, a very stable and reliable electrical system for converting its fundamental frequency into a lower frequency suitable for operating the counting mechanism. In the paper just referred to, a step-down frequency converter was described which included a separate oscillator whose frequency is determined by a periodic circuit in the usual way, together with a system for varying the reactance of the frequency-determining circuit in accordance with variations in the frequency of the piezo-oscillator.

In the system to be discussed here, a piezoelectric oscillator is employed as the intermediate source. But for the step-down frequency converter, a system describing « relaxation oscillations » (3) is adopted because it has been found to offer many advantages for the specific problem in hand. An intermediate frequency of 50 kilocycles is chosen for convenience. One relaxation oscillator having a 10-kilocycle fundamental then provides directly the series of harmonics at 10-kilocycle intervals which are desired for calibration purposes. A relaxation fundamental at 1 kilocycle or even less, directly oscillator can be adjusted to yield a highly stable controlled by the 50-kilocycle source, which operates a small impulse motor, running in air, for the counting mechanism. Furthermore, the controlled relaxation oscillator, if properly designed, is an extremely simple piece of equipment.

Two general types of relaxation have been suggested for use as step-down frequency converters. The simplest is a neon discharge tube,

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(*) See bibliography page 26.

employed in virtue of its so-called cut-off characteristic to sustain oscillations in a circuit comprising a direct-current source, a resistance and a condenser. The oscillations of such a circuit are rich in harmonics and if a second oscillation of a higher frequency is injected into the circuit, the relaxation oscillation may assume a frequency which is an integral submultiple of the injected frequency. It is possible to maintain an oscillation in such a circuit whose fiftieth harmonic coincides with the injected frequency. But the behaviour of this control effect on such high orders is relatively unsatisfactory, as minute variations in either the injected voltage or the direct voltage are likely to destroy the control. The other type of oscillator is the Abraham-Bloch multivibrator. Doubtless there are many other forms of relaxation oscillator which present similar characteristics but a modified multivibrator has proved so satisfactory that no others have been investigated.

The multivibrator consists essentially of an aperiodic circuit in which oscillations of irregular waveform are sustained by a triode excited by a second triode which provides the proper phase relation .for maintenance. It was first used as a rich source of harmonics, in which the fundamental constituent is determined by and probably maintains a constant phase relation with a low-frequency injected oscillation. In its usual form it therefore constitutes a frequency multiplier or step-up frequency converter suitable for comparing high frequencies with a low-frequency standard. Some time ago one of the present authors (4) suggested the possibility of controlling a multivibrator at a fundamental frequency which is an integral submultiple of the injected control frequency, thus making it a step-down frequency converter.

3. Harmonic Control of Multivibrator. — No adequate mathematic analysis of the action of the multivibrator has been given. In the practical case large voltage amplitudes are encountered, carrying the operating points of the vacuum tubes far beyond the region of the characteristic which might be adequately treated under limited series solutions (for small amplitude oscillations) such as Van der Pol's (3). But large amplitudes are required to obtain an extended series of harmonic frequencies of useful amplitude. It thus appears that the only feasible investigation of multivibrator oscillations, meeting our physical requirements, demands sufficiently complete experimentation to permit valid generalizations to be drawn.

The basic assumption of integral ratios between the harmonics and fundamental *emitted* by a multivibrator allows frequency comparisons to be made, but does not necessarily imply that the controlled multivibrator has a harmonic frequency, of value equal to the frequency of the controlling source, and of invariant phase with respect to this source. A regular, or irregular, variation in phase might conceivably exist.

We arbitrarily define the « controlled » state for the multivibrator as that state of operation in which one of the multivibrator harmonics does not change phase with respect to the fundamental frequency of the controlling source by more than 360 electrical degress in any arbitrary time interval. Then, by the assumption of integral harmonic frequencies, the fundamental frequency of the multivibrator is an exact submultiple of the controlling frequency. We shall examine the experimental conditions for permanently establishing this controlled state on the desired harmonic order.

All the experiments have been carried out with no inductance, save that of strays, in the circuits of the multivibrators because it appeared logical to reduce the electrical inertia to a minimum when searching for the most stable and unambiguous control condition.

Preliminary studies indicated that the control stability in any multivibrator was increased by the injection of the control voltage into the common plate lead of the multivibrator tubes, as compared with injection into the circuits of either tube individually. Such increased stability is obtained, however, only if the multivibrator tube circuits are unsymmetrical so that an appreciable plate current exists in the common lead.

The use of the unsymmetrical multivibrator in this connection resulted from earlier work by one of the authors with the symmetrical arrangements. Dissymmetry was first attained through the use of tubes of different type, having widely differing filament emissions. Later work showed the same result was obtained with tubes of the same type, if the circuit constants were made dissymmetrical, as by the use of resistances 20 to 50 times as great in one triode plate circuit as in the other.

As a result of this dissymmetry, one triode operates as a « throttle », the operating point sweeping across the entire characteristic from saturation to cut-off, while the other triode operates substantially as a normal amplifier. This type of operation, no matter how attained, is characteristically favorable for stable control.

A tube is employed between the controlling source and the multivibrator which does not function primarly as an amplifier, but as a one-way relay, whose purpose is to isolate the standard source from reactions due to the multivibrator. This is not only generally desirable, but it is a necessity if the standard is to maintain its frequency with extreme constancy. An ordinary vacuum tube amplifier circuit is not sufficient when the controlling frequency is as high as 50 k. c. Either a tetrode, utilized as a « screened grid » amplifier, must be employed, or a carefully neutralized triode.

The schematic circuit arrangement for a single controlled multivibrator is given in figure 1. In the absence of the tetrode and the resistance R, the uncontrolled multivibrator remains. In this work the resistances were fixed variation of the fundamental frequency of the multivibrator attained by simultaneous variation of the capacities, C. In the uncontrolled state, variation of these capacities produces a corresponding smooth variation of fundamental frequency of the multivibrator.

The application of a controlling voltage, e_c to the grid of the isolating tube, results in the injection of a voltage of the same frequency into the multivibrator circuit. Provided that the voltage is sufficiently great, that is, greater than a few hundredths of a volt, variation of the condensers, C, no longer produces a smooth and continuous change of fundamental frequency of the multivibrator. For certain separated ranges of values for C, the fundamental frequency of the multivibrator assumes discreet values, these being submultiples of the control frequency and invariant over the particular range of C. Between the ranges of C at which these discreet frequencies exist there are « transition » ranges in which no stable value exists for the fundamental frequency of the multivibrator. In these transition ranges the multivibrator attempts to oscillate in the controlled and uncontrolled states simultaneously, or, if the control voltage be sufficiently great, in adjacent controlled states. When observed by an oscillograph, it is seen that in the latter case the fundamental oscillation of the multivibrator consists of a number of cycles of one discreet frequency and then one, or more, cycles at another discreet frequency. The oscillations alternate between the two frequencies in an irregular manner, there being no definite number of cycles in sequence of either of the two frequencies.

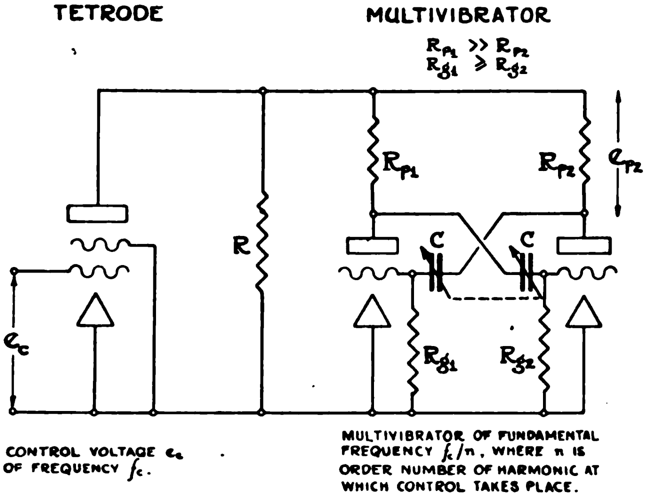
TETRODE
MULTIVIBRATOR
$R_{p1} >> R_{p2}$
$R_{g1} \geqslant R_{g2}$
R_{p1}
R_{p2}
e_{p2}
R
C
C
e_c
R_{g1}
R_{g2}
CONTROL VOLTAGE e_c OF FREQUENCY f_c.
MULTIVIBRATOR OF FUNDAMENTAL FREQUENCY f_c/n, WHERE n IS ORDER NUMBER OF HARMONIC AT WHICH CONTROL TAKES PLACE.

FIG. 1.

With small values of controlling voltage the operation is generally such that in the transition ranges of capacity, between those at which discreet and invariant values of fundamental frequency are obtained, the multivibrator oscillates in the uncontrolled condition. The regions in which control is attained are well defined and the controlled state is fairly stable. This mode of operation has been termed the « under-voltaged controlled state ». If the control voltage be increaded in magnitude, the transition ranges of capacity over which uncontrolled or unstable operation is obtained, are reduced progressively as the control voltage magnitude is raised, until finally the multivibrator fundamental frequency changes abruptly from one mode to the next upon varying the capacities through a very small transition range. This state of control has been termed the « over-voltaged controlled state » and represents that condition of operation which is believed to be the most stable and most desirable. In this condition, variation of capacity from maximum to minimum results in the production of a series of discreet fundamental frequencies, the number of such frequencies which may be obtained being dependent upon the range of variation of capacity and upon the order of control which has been set up.

If the control voltage be increased beyond the point at which the transition ranges first shrink substantially to zero an effect which may be termed « drawing » is produced. This drawing effect consists of a progressive increase in the multivibrator fundamental frequency through discreet steps representing the successive harmonic control orders, as the amplitude of the control voltage is increased. In other words, the fundamental frequency is drawn toward the control frequency as the control influence is made stronger. If a particular control order is desired this drawing effect must be compensated by an increase in the time constant of the multivibrator. But this in turn tends to remove the time constant of the multivibrator circuit away from the fundamental frequency at which it is being forced to oscillate, which ultimately reduces the control stability on its own account. The net result of these opposing effects is the appearance of a fairly definite *optimum value* of control voltage for any given harmonic order.

We come now to somewhat more generalized conclusions concerning the dependence of the control range, the control order and the waveform of the multivibrator oscillations upon variations of control voltage magnitude, variations in multivibrator fundamental frequency as produced by *symmetrical* variations in the multivibrator circuit constants and variations in the *degree of dissymmetry* of the multivibrator circuit produced by a non-symmetrical variation of the circuit constants. These considerations are best indicated by an outline :

1. Variations in control voltages e_c.	Small e_c . .	Limited control range, though control is stable within range. Waveform of same type for various orders of control.
	Large e_c . .	Maximum control range ; further increases of control voltage produce changes in order of control by « drawing », with narrowing of control range if e_c be made large enough.
2. Variations in mv. fundamental frequency due to symmetrical changes in circuit constants. (C, C, varied).	.	Control order changes in successive steps to lower orders as fundamental frequency of mv. is raised toward control frequency. Control range narrow with small e_c ; control range wide with large ee_c. Waveform of same type for the various control orders.
3. Variations in degree of dissymmetry of mv. circuit. (Rp_2 only varied).		Control order remains constant. Waveform alters in discreet steps to forms in which the « positive » and « negative » portions of the wave are in *integral ratios of time*, the total time remaining constant.

Based upon the experimental evidence, an important generalization may be drawn. *Symmetrical changes* in *circuit constants* produce effects similar to *symmetrical changes* in *control voltage magnitude.* (Changes in control voltage are inherently symmetrical in the arrangement displayed here since the same voltage is injected in the plate circuits of both tubes.) These effects are characterized by control at successive orders with no major changes in the waveform. Changes in the *degree of dissymmetry* of the circuit result in *discreet changes of waveform*, the control order usually remaining fixed. These changes of waveform are characterized by discreet changes in the ratio of time of negative to time of positive portion of cycle, the total time remaining constant.

It is worthy of note that under no operating condition was the stability of control improved by distorting the waveform of the control voltage to produce harmonics which might « lock in » with the higher harmonics of the multivibrator. This appears to be due to the fact that the effect which we term « control » occurs at a certain definite phase relation between the control wave and the corresponding multivibrator harmonic, and the phase differences between the higher harmonics of both sources although invariant, may either aid or oppose the control which is already established.

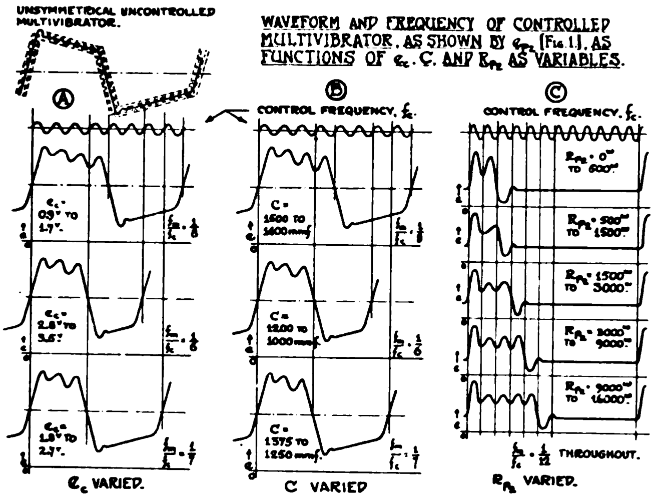
UNSYMMETRICAL UNCONTROLLED MULTIVIBRATOR.
WAVEFORM AND FREQUENCY OF CONTROLLED MULTIVIBRATOR, AS SHOWN BY e_{p_2} (FIG. 1), AS FUNCTIONS OF e_c, C, AND R_{p_2} AS VARIABLES.
Ⓐ
Ⓑ
Ⓒ
CONTROL FREQUENCY, f_c.
CONTROL FREQUENCY, f_c.
e_c = 0.9 V TO 1.7 V.
$\frac{f_m}{f_c} = \frac{1}{9}$
e_c = 2.8 V TO 3.6 V.
$\frac{f_m}{f_c} = \frac{1}{8}$
e_c = 1.8 V TO 2.7 V.
$\frac{f_m}{f_c} = \frac{1}{7}$
e_c VARIED.
C = 1500 TO 1400 mmf
$\frac{f_m}{f_c} = \frac{1}{9}$
C = 1200 TO 1000 mmf.
$\frac{f_m}{f_c} = \frac{1}{8}$
C = 1375 TO 1250 mmf.
$\frac{f_m}{f_c} = \frac{1}{7}$
C VARIED
R_{p_2} = 0 Ω TO 500 Ω
R_{p_2} = 500 Ω TO 1500 Ω
R_{p_2} = 1500 Ω TO 3000 Ω
R_{p_2} = 3000 Ω TO 9000 Ω
R_{p_2} = 9000 Ω TO 16000 Ω
$\frac{f_m}{f_c} = \frac{1}{12}$ THROUGHOUT.
R_{p_2} VARIED.
e
0

FIG. 2.

The oscillograms of figure 2 indicate the phenomena observed. These oscillograms are line drawings of experimental observations of the plate current in that multivibrator tube which operates through the low external plate resistance. This current has in all cases the same general waveform as the relatively minute plate current in the throttle tube and also the current in the common plate circuit which includes the control tube.

Diagram A indicates the changes resulting from variations of the magnitude of the control voltage, all other factors remaining constant. The waveform remains essentially the same. As the control voltage is raised, the fundamental controlling voltage.

These observations suggest a reasonable explanation of the fact that in a symmetrical multivibrator a strong preference is evidence for control at even ratios, because of the symmetry of the « positive » and « negative » portions of the wave. With the dissymmetrical multivibrator such a preference does not appear to exist, which is explainable on the basis that the inherently unsymmetrical waveform readily adjusts itself so that one portion of the wave occupies a time interval equal to that of an odd number of cycles of the controlling frequency, while the other portion of the wave occupies a time interval corresponding to an even number of cycles of the control frequency. These conditions are illustrated, in particular, by the lower diagram, for the frequency ratio of 1/7. Here the « positive » portion of the wave occupies a time interval of 3 cycles of the control frequency, while the « negative » portion occupies a time interval of 4 cycles. If the waveform is more nearly symmetrical, the multivibrator must be forced to operate dissymmetrically, by the controlling influence, in order that odd frequency ratios may be obtained, consequently requiring a greater controlling influence than in the unsymmetrical case.

In diagram B are shown sketches of the waveforms resulting from variation, in a symmetrical manner, of the capacities C of the multivibrator circuit, all other factors remaining constant. The waveform is seen to remain essentially constant but the frequency assumes three discreet values, bearing the ratios 1/9, 1/8, and 1/7 to the controlling frequency. The most stable adjustment of capacities is at a value slightly below the middle of the control range.

Thus these two diagrams, 2A and 2B, illustrate the equivalent effects of symmetrical changes of controlling voltage and of circuit constants, upon the waveform and frequency of the multivibrator oscillations.

Diagram 2C indicates the changes in waveform as the lower of the two plate circuit resistances of the multivibrator was varied. In this case Rp_1 was 400,000 ohms, Rp_2 variable between 0 and 18,000 ohms. The multivibrator remained in control at all values of Rp_2, with a fundamental frequency which was one-twelfth of the controlling frequency. The successive discreet waveforms were obtained over considerable ranges of values for Rp_2, as indicated by the marginal notations in the figure. The integral ratios of the times for the two portions of the cycle are clearly indicated, as well as the manner in which the serrations due to the controlling frequency shift by single units as Rp_2 is continuously varied.

The assembly finally employed consists of two multivibrators in cascade the choice of ratios being determined by the available standard frequency, the normal frequency of the clock motor and the fact that a series of harmonics based on 10 kc. fundamental frequency are desired for calibration purposes. While frequency ratios, with a single multivibrator, of the order of 50 may be obtained with stable operation, it would have been necessary to utilize a second multivibrator in this case to obtain the desired harmonic series. Therefore the multivibrators were compounded, the first operating with a frequency ratio of 5, and whose fundamental frequency was therefore 10 kc., and the second with a frequency ratio of 10, whose fundamental was consequently 1 kc. Provision was made for a small coupling coil to be inserted in the first multivibrator circuits so that the series of 10 kc. harmonics could be utilized externally. The complete wiring diagram of the assembly is given in figure 4, on which the values of the various circuit constants are shown, as well as the normal ranges of supply voltages, through which stable control was obtained.

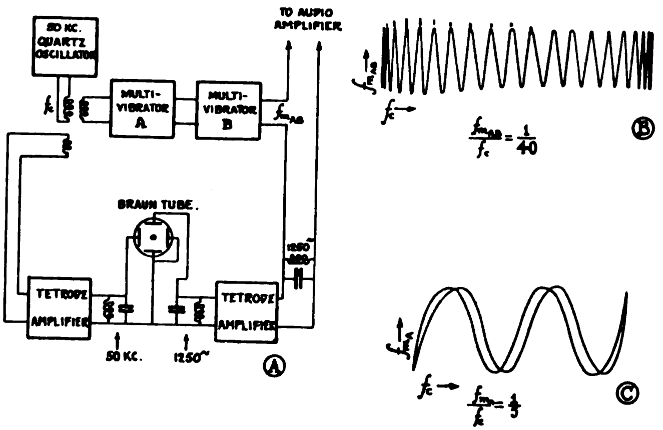

FIG. 3.

With careful adjustments of the condensers, C, *within the control range,* stable operation has been attained for the following ranges of supply voltages, the frequency ratio being 50 for the entire assembly :

e_c from 1.8 to 2.8 volts, at 50 kc.
E_f from 3.5 to 6.0 volts,
E_p from 90 to 135 volts (or more).

While ranges of supply voltages such as given above have been attained many times, the ranges shown on the diagram are more indicative of nominal conditions, in which no excessive care has been used in making the adjustments. Under these conditions no difficulties are encountered in operation while « trickle charging » the filament and plate batteries from the commercial 60 cycle power line.

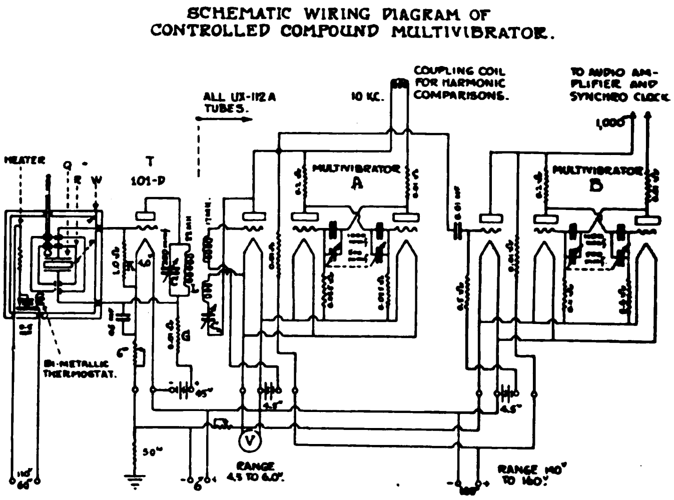

FIG. 4.

The foregoing observations indicate that by injecting a 50-kilocycle voltage into the circuits of the compound multivibrator it is possible to establish a highly stable condition in which the fundamental and all the harmonics of both multivibrator elements are constant in frequency to the same degree that the injected voltage is constant. Moreover the fundamental output at one kilocycle bears every indication of being precisely controlled by the injected voltage. However, the exact mechanism of this control effect has not yet been analyzed, and we still have no direct experimental evidence that, when the multivibrator operates in a condition which has the physical characteristics of being « controlled », its fiftieth harmonic actually bears a constant phase relation to the control oscillation.

As a final critical test of this point, simultaneous observations of the control oscillation and the fundamental of the multivibrator were made by means of a Braun tube. The circuit arrangement is indicated in figure 3 A. Two tetrode amplifiers were used, one coupled loosely to the quartz oscillator furnishing the control voltage and the other to the output of multivibrator A or multivibrator B. The output circuits of the amplifiers were carefully tuned so as to emphasize the fundamental frequencies of the standard oscillator and the multivibrator. When the circuits were not accurately resonant, the patterns indicated by the Braun tube were highly distorted. For the operation of the compound multivibrator, with a frequency ratio of 5 in the first and of 8 in the second, the pattern given by the Braun tube appeared as sketched in figure 3B.

The form of the pattern clearly indicated the frequency ratio of 40, remaining entirely stationary. As the tuned circuits were changed, the phase of one frequency component could be shifted with respect to the other, of course, but with the circuits fixed, no visible fluctuations in frequency, phase or amplitude took place. Upon changing either the resistances or the capacities of the multivibrator circuits, *keeping within the control range*, a change of phase was indicated by the pattern. This change of phase was « permanent », — that is, varying the multivibrator constants displaced the phase and produced a new form of pattern, which form persisted until some further change was made.

A similar test, made between the frequency of the quartz oscillator and the output of the first multivibrator, gave a pattern which indicated the frequency ratio of 5. As before, changing the multivibrator constants *within the control range* had the effect of changing the phase between the two voltages acting on the Braun tube, but for fixed values of the constants, the phase remained fixed over indefinite periods. In both of these cases, variation of the circuit constants to a point where the control order changed indicated that a maximum phase variation of not more than 30 degrees (between the control wave and the synchronized harmonic of the multivibrator) could take place before the multivibrator jumped out of control at the desired order. In this test the multivibrator was brought to the edge of a transition range and the amplifiers were then adjusted to obtain the « in phase » pattern on the Braun tube screen. The multivibrator constants were then changed across the control range to the opposite transition point the resulting change in phase being noted.

Moreover, the controlling frequency may be varied slight amounts, the multivibrator remaining in control. As the variation in control frequency is made, the multivibrator suffers a slight phase displacement with respect to the standard frequency, but as long as the phase is not displaced beyond the limit of 30 degrees, approximately, the phase takes up the new value and remains constant.

Continuous observations over periods of ten hours have not indicated any perturbations of frequency, phase or amplitude of sufficient duration to register on the Braun tube. After making the amplifier circuit adjustments necessary to obtain a distinctive pattern, on which any slight drift in phase would be readily observable, intermittent observations over periods of several days have failed to show any change whatever in the phase of the synchronized multivibrator harmonic with respect to the control voltage.

We conclude from these observations that this state of oscillation of the multivibrator in the presence of a high-frequency injected oscillation which we have called the « controlled » oscillation throughout the discussion, is in fact an oscillatory state wherein the appropriate multivibrator harmonic bears a constant and permanent phase relation to the injected oscillation. Moreover the frequency of this harmonic and hence of the fundamental follows any drift or perturbation in the frequency of the control oscillation without dropping out of synchronism even a single cycle. The unsymmetrical multivibrator therefore constitutes a stable submultiple generator suitable for converting the vibrations of the piezo oscillator into the rotation of a clock train.

4. The Piezo Oscillator. — The circuit of the 50-kilocycle piezo oscillator is shown in figure 4. The piezo element P is a normal-cut quartz bar, vibrating in the direction of its length; its approximate dimensions are 5.6 × 2.2 × 1.4 cm. The mounting is shown in figure 5. The bar is balanced on a metal support C having a felt wedge on its upper surface and confined between heavy metal condenser plates B by the pressure screw E, carrying a felt pad, the whole assembly being mounted on a base of insulating material D. The holder and quartz bar are mounted in a constant-temperature chamber. This unit consists of an aluminum casting of high heat capacity containing a cavity for the quartz condenser; the casting is surrounded by an insulating layer, which is in turn enclosed in a closed metal box, heat is supplied from coils distributed around this second metal box, the heating circuit being closed through a bimetallic thermostat positioned, with the heating coils, outside the second container. The whole is enclosed in a heavily insulated outer box of wood.

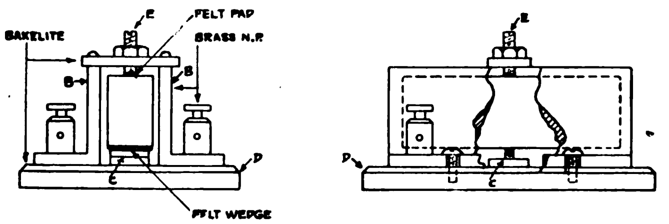

FIG. 5.
Quartz bar mounting.

The quartz box is maintained in oscillation by the triode, operated from plate circuit batteries which are independent of the multivibrator batteries.

The quartz oscillator circuit is one of the general class in which sustained oscillations are impossible without the quartz bar. This type of circuit was chosen because experience with numbers of piezo-oscillators used as secondary standards has indicated that the frequency of the oscillator is in general more precisely determined by the mechanical vibration of the quartz if no other periodic element is present which can support sustained oscillations independent of mechanical vibrator. For this reason the regenerative element, which is added to augment the regeneration through the grid-plate capacity of the triode, is a pure resistance. The load in the plate circuit, consisting of inductance L shunted by capacity C, is far removed from resonance at the frequency of the quartz bar. It merely represents a convenient method of obtaining the high inductive reactance required to sustain oscillations. The coil has an inductance of 20 millhenries and the capacity is normally set at about 0.0003 microfarads, thus providing an inductive reactance of approximately 15,000 ohms. This reactance is still approximately proportional to the frequency in the operating region. The capacity C was added, not to augment the voltage available form the oscillator, since an excess of amplification is provided in order to avoid the necessity of large amplitudes in the oscillator circuit, but merely to provide a means for making fine corrections on the oscillator frequency.

The damping coefficient of the quartz bar itself has not been determined, but the characteristics of the whole oscillator in the actual operating region are as given in the following table. The figures here are the fractional change in frequency, positive or negative, for an increase of two per cent in the specified voltage or circuit element.

Two per cent increase in	Fractional change in frequency
Plate voltage . .	-0.02×10^{-6}
Filament voltage.	-0.04×10^{-6}
Resistance R_p . .	$+0.8 \times 10^{-6}$
Resistance R_g . .	-0.1×10^{-6}
Capacity	-3.0×10^{-6}

The temperature coefficient of the quartz bar and holder combined is 5.4×10^{-6} per degree centigrade.

5. Determination of an Unknown Frequency between 500 and 1,500 kc. — The specific purpose of this development was to provide means for accurately adjusting a secondary standard oscillator to one of the even decimal frequencies between 500 and 1,500 kilocycles. The secondary standards are piezo-oscillators including quartz plates mounted in holders with adjustable air gaps. The plates are adjusted to within one-tenth of one per cent by grinding, and the final setting is made by adjusting the air gap with a screw provided for this purpose which is then locked. The process of referring the adjusted frequency to a standard time interval is carried out by coupling the oscillator under test loosely to the calibration coil of multivibrator A (see figure 4) which has a fundamental of 10 kc., then coupling a third oscillator and detector loosely to the combination, and listening with telephone receivers to the output of this detector as the oscillator under test is adjusted to beat zero with the appropriate harmonic of the multivibrator. This harmonic can be identified without difficulty with a subsidiary wavemeter, although there is usually not the slightest ambiguity as to the order of the harmonic, since the preliminary adjustment of the test oscillator by grinding the quartz is carried out with the aid of a heterodyne wavemeter calibrator to an accuracy of 0.1 % and the beat note between the oscillator under test and the multivibrator harmonic is normally well within the audible range before the final process is begun. Since a third frequency is superposed on the output of the multivibrator and the test oscillator, the frequency of the test oscillator can be adjusted aurally with a precision defined by about one beat in five seconds between it and the multivibrator.

When this adjustment has been made, the frequency of the oscillator under test is known directly in terms of the frequency of the quartz bar at the time of the measurement, and thus in terms of the standard time interval, to a precision which depends upon how closely the frequency of the quartz is maintained at its average value.

The standard time interval now employed in this work is one mean solar day, as indicated by the radio time signals from the U. S. Naval Observatory. The small motor used as an oscillation counter is geared down through a clock train to a large second hand making one rotation per minute. The synchronous impulse motor has a toothed rotor of 120 teeth, and is driven by two U-shaped magnets around which the drive coils are wound. The dial reading is compared visually with the standard time signals with a probable error of not over 0.05 second, the mean being derived from the consecutive observations. Thus the mean frequency over each twenty-four hour interval is observed with a probable error slightly over one-half part in a million. The use of a longer standard time interval, to reduce the error in observing the mean frequency will not be justified until substantial reductions are made in the probable short-period perturbations from the mean frequency.

The fluctuation of the piezo oscillator frequency during the first ten days in August, 1928, is shown graphically in figure 6. Each point in this curve indicates the average frequency during the preceding 24-hours interval except in two cases, where the interval was 48-hours. The horizontal line marked « Mean Frequency 50007.6 cps. » is the average for ten days. The maximum deviation from the 10-day mean is 0.36 cycle during the fourth and fifth days.

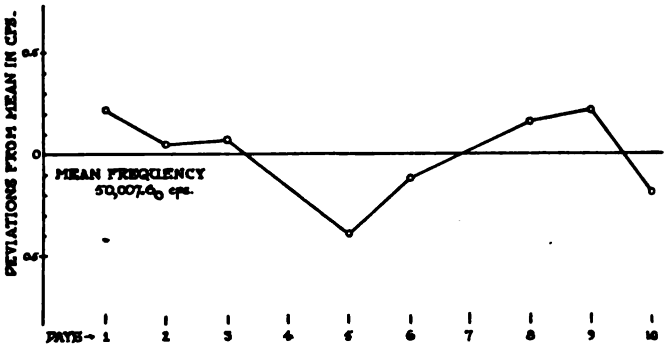

FIG. 6.

The limitations at present imposed upon the commercial standards to be calibrated require that they be adjusted to an accuracy of ten parts in one hundred thousand or better. The 24-hour mean frequency of the calibration oscillator is known to well within one part in one million. The battery voltages are held within such limits that the short-period fluctuations attribuable to them are probably negligible compared with the fluctuations due to temperature. A definite correlation was observed between the temperature and the long-period fluctuations of figure 6. It is reasonable to assume that the momentary perturbations from the 24-hour mean are not greater than the maximum fluctuation from the mean observed in a long interval, which is of the order of eight parts in one million. Thus if the calibration is performed with a precision defined by 0.2 cycle in 500,000 or more, the normal accuracy at present attainable in adjusting the oscillator under test is about eight parts in one million which is safely within the current requirements. The piezo-oscillator has recently been adjusted to a mean frequency of 50,000.17 cps., and in most oscillator calibrations the correction to 50 kc. is neglected, allowing the adjustment to zero beat of the oscillator under test.

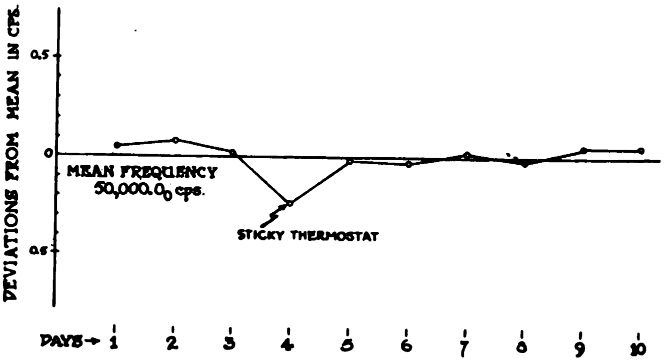

FIG. 7.

The variations in mean frequency of the piezo-oscillator as indicated in figure 6, while insignificant as regards present requirements, are of course much too large for a standard of high precision, and are probably not representative of the possible performance of the system under the most favorable conditions which modern technique of temperature and circuit control may afford. But the whole calibration system now appears to have been brought to a point where the mechanical details are the only elements requiring further improvement.

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SUR UN ONDEMÈTRE ABSOLU
POUR LA MESURE DES TRÈS PETITES LONGUEURS D'ONDES

par F. DACOS,
Chargé de Cours à l'Institut Montefiore, Liége, Belgique.

Sommaire. — L'ondemètre décrit ci-après est basé sur la déviation des rayons cathodiques par un champ électrique.

Deux plateaux déviants sont connectés au circuit où l'on veut mesurer la longueur d'onde. La très grande impédance de l'appareil fait qu'une puissance très faible suffit pour faire la mesure. Le dispositif convient pour les ondes inférieures à 6 mètres et la précision est satisfaisante.

Principe. — Dans une ampoule vide de gaz, une cathode incandescente C recouverte d'oxyde de strontium, donne un pinceau d'électrons convenablement délimité par les écrans E_1 et E_2 munis de fentes (fig. 1). Le pinceau cathodique rase un écran phosphorescent placé entre les deux plateaux déviants P_1 et P_2, et disposé normalement à leur plan.

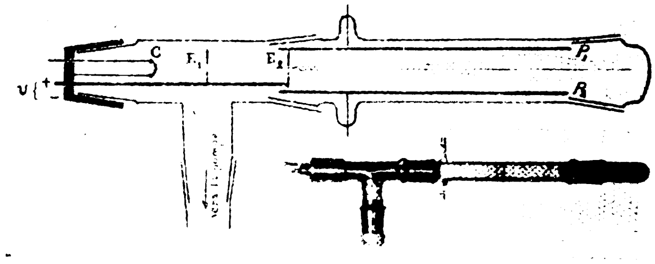

FIG. 1.

P_1 et P_2 sont reliés aux deux armatures du condensateur du circuit oscillant traversé par le courant dont on veut mesurer la fréquence.

En l'absence d'oscillations, l'afflux cathodique se propage en ligne droite suivant l'axe de symétrie de l'appareil pris comme axe des X.

Désignons par h la valeur instantanée du champ électrique qui existe entre P_1 et P_2 et supposons que ce champ soit une fonction simplement sinusoïdale du temps.

$$h = H \sin \omega t.$$

L'équation différentielle du mouvement des électrons suivant la direction des y est, avec une notation évidente,

$$\frac{d^2y}{dt^2} = H \frac{e}{m} \sin \omega t = K \sin \omega t,$$

qui donne, après deux intégrations successives,

$$y = -K \sin \omega t + C_1 t + C_2$$

C_1 et C_2 étant les constantes d'intégration.

Pour trouver la relation entre x et y, nous remarquerons que le mouvement des électrons dans la direction de l'axe des x est uniforme.

$$\frac{dx}{dt} = V.$$

Il s'ensuit que

$$x = Vt + C_3.$$

Comptons les temps à partir du moment où le champ électrique est nul.

L'un des électrons du pinceau cathodique pénètre dans le champ déviant à l'instant t_1, où celui-ci a la valeur h, on a

$$C_3 = -Vt_1 \quad \text{et} \quad t = \frac{x + Vt_1}{V}.$$

La trajectoire de l'électron est donnée par l'équation

$$y = C_2 + \frac{C_1}{V}(x + Vt_1) - \frac{K}{\omega^2} \sin \frac{\omega}{V}(x + Vt_1).$$

Si nous introduisons les conditions à l'origine

$$t = 0, \quad x = 0, \quad y = 0 \quad \text{et} \quad \frac{dy}{dx} = 0,$$

nous trouvons

$$C_1 = \frac{K}{\omega} \cos \omega t_1 \quad \text{et} \quad C_2 = \frac{K}{\omega^2} \sin \omega t - \frac{K}{\omega} t_1 \cos \omega t_1.$$

En conséquence, l'équation de la trajectoire devient :

$$y = \frac{K}{\omega^2}\left[\sin \omega t_1 + \frac{Kx}{\omega V} \cos \omega t_1 - \frac{K}{\omega^2} \sin \frac{\omega}{V}(x + vt)\right].$$

Cette relation montre que les valeurs de x sont indépendantes du temps t_1. En effet, de

$$\frac{dy}{dx} = \frac{\omega}{V} \cos \omega t_1 - \frac{\omega}{V} \cos \frac{\omega}{V}(x + Vt) = 0$$

on déduit que

$$\cos \omega t_1 = \cos \frac{\omega}{V}(x + Vt_1)$$

ou

$$x = (\pm 1 - 1)\omega t_1 + 2k\pi$$

et en introduisant la valeur $x = 2k\pi$ dans

$$\frac{d^2y}{dx^2} = \frac{\omega^2}{V^2} \sin \frac{\omega}{V}(x + Vt_1)$$

on trouve que la dérivée seconde est positive.

Les valeurs $x = 2\pi k$ rendent donc y minimum.

Les trajectoires des électrons pénétrant dans le champ déviant à des instants t_1 différents, présentent toutes les ordonnées minima aux mêmes abscisses, x_1, x_2, etc.

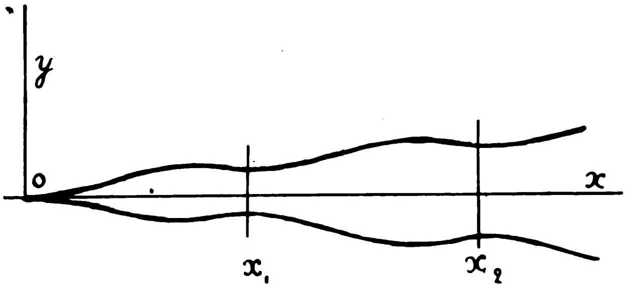

FIG. 2.

La figure 2 donne la forme schématique de l'enveloppe de toutes ces trajectoires.

La mesure des différentes abscisses x_1, x_2,... permet l'évaluation de la longueur d'onde, lorsque la vitesse des rayons cathodique est connue. Soit X la différence $x_1 - x_2$, évaluée en centimètres, et U la différence de potentiel, exprimée en volts, à laquelle le pinceau électronique est soumis, entre la cathode incandescente et l'anode. On a

$$X = Vt \quad \text{et} \quad V^2 = 2\frac{e}{m}U, \text{ de sorte que } \lambda = c\frac{X}{\sqrt{U}} = 503\frac{X}{\sqrt{U}} \text{ cm}$$

Comme

$$\frac{d\lambda}{\lambda} = \frac{dX}{X} + \frac{dU}{2U}$$

et comme il est possible d'évaluer X à un pour cent près, ainsi qu'il appert de la figure 3, et U à moins du dixième pour cent près par une méthode potentiométrique, l'approximation de la longueur d'onde par la méthode décrite est de l'ordre du pour cent.

Au point de vue de l'approximation du résultat, cette méthode est susceptible d'une amélioration notable moyennant l'adjonction au dispositif expérimental des écrans E_2, E_3, E_4, pourvus comme E_1, d'une fente parallèle aux plateaux déviants P_1, P_2 (fig. 4). Elle devient ainsi une méthode de zéro.

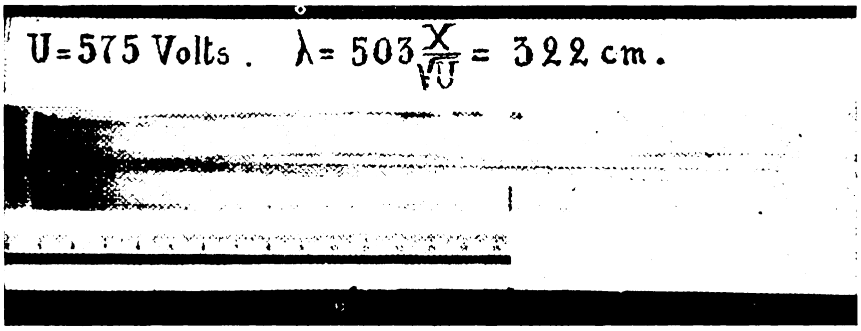

FIG. 3.

En l'absence de tout champ électrique entre les deux plateaux P_1 et P_2, le pinceau cathodique traverse successivement les fentes des quatre écrans et tombe sur une électrode Z reliée à un galvanomètre ou à tout autre système mesurant la charge électrique communiquée par l'impact des électrons.

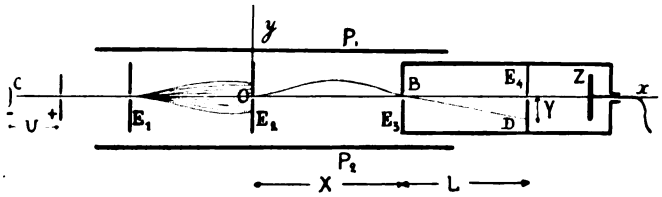

FIG. 4.

L'afflux cathodique délimité par le premier écran pénètre dans la zone E_1 E_2 et s'y trouve soumis à l'action du champ déviant h qui s'étend entre E_1 et E_3.

Les électrons ne passent dans l'espace E_2 E_3 qu'au moment où $h = 0$, la trajectoire, dans cet espace E_2 E_3 de ceux d'entre eux qui traversent l'écran E_2, est définie par les équations précédentes où l'on pose $t_1 = 0$.

Avec l'origine des coordonnées reportée en E_2, l'équation de cette partie de leur trajectoire s'écrit donc

$$y = \frac{He}{\omega^2 m}\left(\frac{\omega x}{V} - \sin\frac{\omega x}{V}\right).$$

En réglant la tension U de manière à modifier convenablement la vitesse V, on peut s'arranger de façon à ce que le premier minimum de y coïncide avec E_3.

La tangente à la trajectoire en ce point, déduite de la dernière équation, est la direction que suivront les électrons au delà de l'écran E_3 à partir duquel ils ne sont plus soumis au champ déviant h.

Dans le cas du réglage parfait de V, cette tangente coïncide avec l'axe des x_1 et z, frappé par les électrons qui traversent aussi l'écran E_4, prend la charge Q.

Si la tension U n'est pas convenablement ajustée, la tangente en E_3 est, par exemple, le segment de droite BD qui frappe l'écran E_4 en un point d'ordonnée Y.

L'électrode Z, ne recevant pas d'électrons dans ces conditions, ne se charge pas.

BD fait avec l'axe des x un angle β donné par

$$\operatorname{tg}\beta = \frac{He}{\omega Vm}\left(1 - \cos\frac{\omega x}{V}\right)$$

et l'ordonnée Y est définie par

$$Y = \frac{HLe}{\omega Vm}\left(1 - \cos\frac{\omega X}{V}\right).$$

Lorsque Y est plus petit que l'ouverture de la fente E_4, Z prend une charge inversement proportionnelle à Y, en supposant homogène l'afflux électronique qui constitue le pinceau.

Si l'appareil de mesure donne une indication α proportionnelle à Q, le diagramme de $Y = f(\alpha)$ se réduit à deux droites se coupant sur l'axe des x (fig. 5) et on peut poser $Y_1 - Y = k\alpha$.

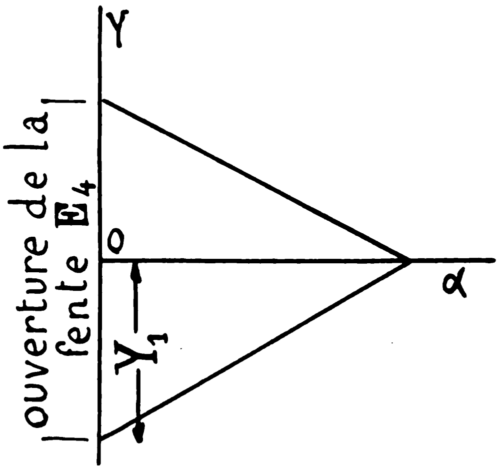

FIG. 5.

La coïncidence de la tangente avec l'axe des x est décelée par α minimum, et, dans ce cas, la distance X (fig. 4) exprime exactement la longueur d'onde cherchée. En effet, pour $Y = 0$,

$$1 - \cos\frac{\omega X}{V} = 0,$$

et par suite,

$$\frac{\omega X}{V} = 2k\pi.$$

La fréquence de l'onde se tire de la relation bien simple $f = \frac{V}{X}$.

Le raisonnement suivant permet de déterminer l'erreur commise dans cette évaluation de la fréquence.

Dans une mesure absolue l'erreur relative limite est évidemment

$$\frac{df}{f} = \frac{dX}{X} + \frac{dV}{V}.$$

L'erreur sur V provient essentiellement d'une erreur sur la différence de potentiel V et on a $\frac{dV}{V} = \frac{dU}{2U}$. La mesure de U peut s'effectuer au millième près.

L'évaluation de la distance X, qui est de l'ordre d'une dizaine de centimètres, peut également se faire à moins du millième. Il en résulte que l'erreur sur la fréquence est alors inférieure à deux millièmes.

Dans la recherche des variations relatives de λ, l'approximation est encore plus élevée. En effet, remarquons qu'une erreur sur U provient d'une erreur de lecture sur α. Recherchons la relation qui lie V à α. Différentions-la

$$Y_1 - Y = Y_1 - \frac{HLe}{\omega Vm}\left(1 - \cos\frac{\omega X}{V}\right) = k\alpha$$

$$d\alpha = \frac{HLe}{k\omega m}\left[\left(1 - \cos\frac{\omega X}{V}\right)\frac{1}{V^2} - \frac{\omega X}{V^3}\sin\frac{\omega X}{V}\,dV.\right]$$

Comme les choses sont réglées de façon que la tangente est à peu près horizontale, c'est-à-dire que la relation $1 - \cos\frac{\omega X}{V} = 0$ est satisfaite, le sinus peut être confondu avec l'arc et il vient

$$d\alpha = \frac{HLe}{2k\omega V^2 m}\cdot\frac{\omega^2 X^2}{V^2}\,dV$$

ou

$$dV = \frac{2mV^4}{HLeX^2\omega^4}\,k\,d\alpha$$

et comme

$$k = \frac{Y_1 - Y}{\alpha} \qquad \text{et que} \qquad v = \frac{\omega X}{2\pi}$$

$$\frac{dV}{V} = 2\frac{mX}{8\pi^3 HLe}Y_1\frac{d\alpha}{\alpha} = 2\frac{\omega^2}{44}\,\frac{XY_1}{10^8 HL}\,\frac{d\alpha}{\alpha}.$$

Le coefficient du terme $\frac{d\alpha}{\alpha}$ est très petit.

Ainsi, s'il s'agit, par exemple de mesurer des longueurs d'ondes d'environ deux mètres,

$$\omega = 2\pi\frac{c}{\lambda 1} = 10^9$$

et si la différence de potentiel U est de l'ordre de 300 volts,

$$V = 10^9 \text{ cm.}$$

Si, d'autre part, $X = L = 100$ cm. et si l'ouverture de la fente E_4 est de deux millimètres, on trouve

$$\frac{dV}{V} = \frac{1}{130}\frac{de}{e}.$$

Pour une lecture de α faite à un pour cent près, l'erreur commise est cette fois inférieure au dix millième.

Modifiée de cette façon, la méthode est susceptible d'une extrême précision.

Liége, le 1er août 1928.

SUR LA MESURE DES LONGUEURS D'ONDES

par G. PESSION et T. GORIO.

Dans ces dernières années l'attention des radiotechniciens s'est particulièrement attachée à la mesure des longueurs d'ondes de transmission ou ce qui revient au même, à la mesure des fréquences qui s'y rapportent. Auparavant ce problème n'avait pas été apprécié à sa juste valeur, et il n'était pas rare de trouver, même dans les stations radiotélégraphiques d'une certaine importance, des ondemètres qui présentaient des incertitudes de l'ordre de quelques unités pour cent.

Le Comité Supérieur Italien de contrôle des postes radiophoniques, créé sous l'initiative de S. E Tittoni et de S. E. Ciano, a reconnu la nécessité de contrôler avec toute la précision possible, les ondes des stations de radio-diffusion. Dans ce but, un dispositif de mesure précise des longueurs d'ondes, moyennes et grandes, c'est-à-dire comprises entre 100 et 30,000 mètres, a été installé à l'Institut Supérieur des Communications.

Ce dispositif est basé sur la méthode bien connue des harmoniques produites par un multivibrateur d'Abraham. La fréquence fondamentale de ce multivibrateur est accordée et synchronisée à l'aide d'un diapason donnant la note ut_5, c'est-à-dire 1024 périodes à la seconde. On procède de façon qu'au moment de l'accord du multivibrateur avec le diapason, il se produise un effet de synchronisation qui permet d'éliminer le contrôle continu de la fréquence du multivibrateur pendant les mesures.

Le principal problème que nous avons essayé de résoudre, est l'étalonnage du diapason par une méthode facile et rapide mais offrant une grande précision.

Comme on le sait, des causes multiples influent la fréquence du diapason. Nous avons tenu compte d'une étude approfondie de ces causes faite par M. le Profr Dye (Proc. of Royal Soc. of London, May 1923).

De ces différentes considérations et des expériences que nous avons faites, il résulte que si l'on cherche une très grande précision $\left(\frac{1}{100\,000}\right)$ le diapason doit être étalonné à chaque mesure, la température restant rigoureusement constante pendant toute l'opération. Pour des mesures de moindre précision $\left(\frac{5}{10\,000}\right)$ on peut utiliser un étalonnage déjà fait, pourvu que le coefficient de température du diapason soit bien connu et que les autres conditions restent les mêmes. La grande difficulté réside dans l'évaluation exacte de la température du diapason; d'après les études du Profr Granfranceschi de l'Institut physique de l'Université de Rome, il convient de déterminer la courbe de refroidissement relatif.

Pour l'étalonnage du diapason et la détermation exacte de la fréquence, nous avons imaginé une méthode simple et rapide, dont la description est donnée à l'article ci-après (p. 31).

Pour la mesure du temps nous avons utilisé une pendule de haute précision de l'Observatoire astronomique du Capitole, qui, à l'intervention de son Directeur le Profr Armellini, avait été relié par ligne spéciale à notre laboratoire. Les tables des valeurs numériques indiquent le degré de précision que l'on peut obtenir au cours d'une journée.

Les principaux avantages de la méthode que nous proposons sont les suivants :

1. Elle permet d'effectuer dans les mêmes conditions de fonctionnement que le multivibrateur d'Abraham, l'étalonnage du diapason immédiatement *avant* et *après* chaque série de mesures.
2. La méthode n'exige pas que l'alternateur utilisé pour l'étalonnage tourne à vitesse constante; ce qui est difficile à obtenir.

Pour montrer le degré de précision que l'on peut aisément obtenir, nous avons appliqué la méthode à l'étalonnage d'un cristal piezo-électrique et à l'étalonnage de l'émission de la nouvelle station radiotélégraphique de Torrenova près de Rome. Pour le cristal, la moyenne de trois mesures faites dans une même série d'expériences avec $t = 13.5$, et $f = 72684,5$; valeur qui diffère de quelques dix-millièmes de celle déterminée par une méthode tout à fait différente à l'Institut de la Marine à Livourne, qui s'occupe d'une manière spéciale de l'étalonnage des quartz. Pour la mesure de l'onde de Torrenova, on a obtenu les valeurs de 2991,2, 2991 et 2990,5 m. différentes également de quelques dix-millièmes.

En conclusion, on voit qu'à l'aide de la méthode exposée, notre Institut peut contrôler d'une façon rapide et précise, entre 100 et 30,000 m., soit les vibrations des ondemètres de commerce et de laboratoire, soit celles des stations d'émission.

Rome, le 6 septembre 1928.

MEASUREMENT OF THE FREQUENCIES OF DISTANT RADIO TRANSMITTING STATIONS

by G. PESSION[1] and T. GORIO[2]

([1]Captain Royal Italian Navy, Rome, Italy; [2]Chief of Radiotelegraph Laboratory, Royal Experimental Institute of Communications, Rome, Italy.)

SUMMARY. — *The equipment installed in the Italian Royal Experimental Institute of the Communications for radio-fréquency measurements is described. The measurements are based upon the utilization of harmonics generated by the Abraham multivibrator controlled by a 1024-cycle tuning fork. The factors which can influence the variation of the tuning fork, with special regard to the action of temperature, are examined. A simple and rapid method is described, which permits of control of the frequency of the tuning fork at the beginning and at the end of each measurement, and determines, with great accuracy, the frequency of the harmonics between which the wavelenght to be measured is included. Such a method consists in comparing the frequency of the tuning fork with that generated by an alternator, and in recording, through a chronograph, the beats included between the two frequencies, the number of revolutions, and frequency of the alternator together with the time furnished by a pendulum of the Astronomical observatory.*

Some examples of calibrations are reported, showing that the degree of precision assured varies from 1 to 5 per 100,000.

The problem of measuring the frequencies of distant radio transmitting stations with the best possible accuracy has recently seriously attracted the attention of workers in the radio field. This problem was not fully appreciated in the past. It was not a rare thing to find wavemeters giving uncertainties of the order of several per cent even in some of the principal radio stations. At the present time the question of precise measurement of the frequencies of radio transmitting stations has become of utmost importance because of the great increase in the number of radio stations, many of which, as for example, broadcasting stations, must be operated simultaneously. As a result, all the most important laboratories are now equipped for radio-frequency measurements of the highest precision.

In Italy the necessity of undertaking special studies and researches in the various government laboratories for the purpose of constructing radio-frequency standards was pointed out last June by Prof. Corbino, President of the Italian Committee of the U. R. S. I.

Recently the Superior Committee for Vigilance on Italian Broadcasting, presided over by Senator Tittoni, recognizing the necessity of checking the frequencies of the emitted waves of the Italian broadcasting stations, charged the Ministry of Communications with the execution of these high precision measurements.

The object of this paper is to describe the apparatus used in the Royal Experimental Institute of Communications for the measurement of long and medium waves between 100 and 30,000 meters (3,000 and 10 kc). The system is based on the well known principle of harmonics produced by means of the Abraham multivibrator. The set employed can also be utilized for the measurement of shorter waves, but we believe that measurements of this kind should preferably be made with other methods, the description of which will be contained in a later paper.

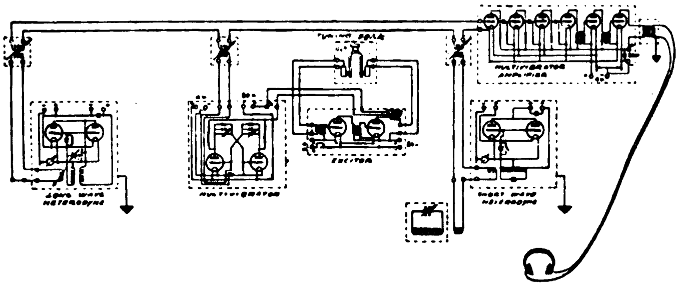

Fig. 1.

Circuit Used in Measuring the Frequencies of Distant Radio Stations.

The multivibrator fundamental frequency is synchronized by means of a tuning fork giving approximately 1024 cycles per second. The tuning fork is operated and maintained in oscillation by the Eccles triode circuit, in the plate circuit of which is inserted the primary of a transformer whose secondary is in series in the multivibrator plate circuit (see fig. 1).

Using this arrangement, when the multivibrator is approximately tuned to the tuning fork frequency a synchronizing effect takes place over a rather broad zone in the neighborhood of the tuning fork frequency. Thus the difficulty of a continuous control of the multivibrator frequency during the measurements is completely avoided.

Two heterodyne generators complete the setup. Figure 2 illustrates the arrangement of the measuring apparatus.

Normally only one heterodyne generator is used. When it is necessary to standardize the shorter waves of the above-mentioned scale of frequencies the other generator is adjusted to the harmonics of the first one. Both heterodynes can be used for determining the order of the harmonics. For instance, the 96th harmonic of the multivibrator can be more easily found as the 8th harmonic of the 12th, or the 6th harmonic of the 16th, than by picking it up directly. Moreover, uncertainty is removed when there is the possibility of determining a particular harmonic by two different methods, especially when there is no possibility of obtaining adjacent harmonics, as in the example above. After the harmonics are identified, the calibration of the wavemeter is easily obtained by measuring with it the frequencies of the electron-tube generators, successively adjusted to the different harmonics.

The measurement of a transmitting station frequency is obtained first by synchronizing one of the generators on the unknown frequency, by means of a non-oscillating receiver, and then measuring that generator frequency with the calibrated wavemeter. If a very high precision is required the heterodyne oscillator may be used as a frequency meter. At the time of the measurement the multivibrator is adjusted to frequencies very near those to be measured and the corresponding reading of the heterodyne condenser observed. By successive interpolation the value of the frequency is obtained, which corresponds to the condenser setting for which the condition of zero beat exists between the heterodyne and the incoming signal. Every possible precaution should be taken during this procedure for maintaining the frequency of the heterodyne constant.

The piezo-electric crystals, now widely used in radio, can also be considered as high-frequency tuning forks, having a low temperature coefficient and sufficient stability to permit their use in the construction of very good secondary standards of frequency. The calibration of a piezoelectric crystal can be obtained by connecting it in the usual circuit, and then measuring its frequency by means of a calibrated electron tube generator. The same procedure described above

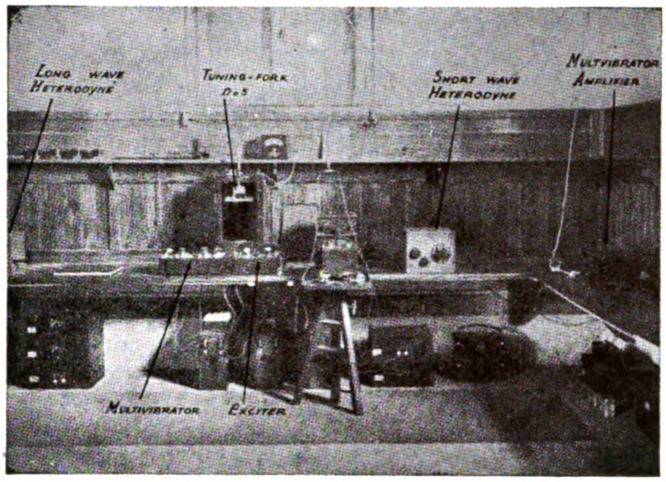

Fig. 2.
Interior View of the Radio-Frequency and Calibratiom Set.

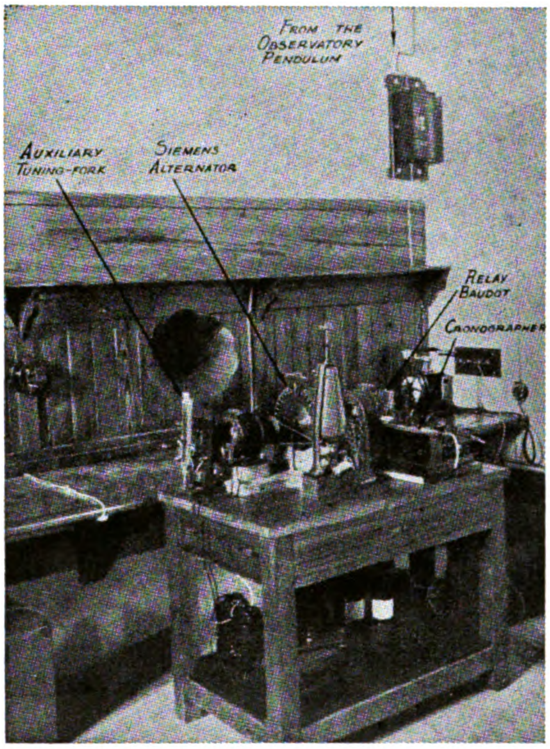

Fig. 5.
Interior View of the Apparatus Used in the Tuning **Fork Oscillation.**

for the measurement of a transmitting station frequency is used.

The tuning fork calibration, which is undoubtedly the principal problem connected with this kind of measurement, has required the development of a rapid and easy method, capable of giving satisfactory precision. This is obtainable in the usual electrotechnical laboratory practice.

First, it is necessary to consider how far it is possible to rely on the constancy of the tuning fork frequency.

It is known that for a tuning fork the number of vibrations of the fundamental frequency is directly proportional to the prong thickness, inversely proportional to the square of its length, and directly proportional to the square root of the fraction E/D, in which E is the modulus of elasticity and D the density of the steel of the tuning fork. Temperature, which affects directly the modulus of elasticity, is the principal factor influencing the frequency of the tuning fork (frequency).

It is known that between N, which represents the tuning fork frequency at temperature t, and N_0, which is the same frequency at zero degrees C, the following relation exists :

$$N = N_0(1 - \alpha t - \beta t^2)$$

Normally, β is very small and t^2 can be neglected but the coefficient α in the common steel tuning forks varies between 0.000088 and 0.00012. Consequently, in the ordinary tuning forks there are frequency variations due to temperature changes which may be in some cases of the order of several parts per thousand.

In the electrically-driven tuning forks, other factors besides the temperature have an effect on the frequency stability, but their effects are not marked. It is known that the tuning fork frequency decreases when the amplitude of the tuning fork vibrations increases. Consequently, it is clear that any variation in the excitation current (that is, the filament current of the vacuum tube), or of the capacity shunting the exciting coils, or of the load applied to the secondary of the transformer, is accompanied by corresponding variations in the tuning fork frequency. A very accurate study of these subjects has been made by Dr. D. Dye (*).

As a result of the above considerations we reached the conclusion that in measurements requiring a high degree of precision (1 to 5 parts in 100,000) it is necessary to calibrate the tuning fork each time before the measurement and to maintain an absolute constancy of temperature. When less precision (5 parts in 10,000) is required a former calibration can be used, but in this case the temperature coefficient must be known and the other conditions (relating to the tubes, plate current, etc.) must be exactly those which were used during the former calibration.

We believe that the exact determination of the tuning fork temperature, which lags behind the temperature of the surrounding air, constitute the greatest difficulty of this measurement. For example, Prof. Gianfranceschi, who conducted investigations on the 870-cycle standard tuning fork of the Physical Institute of Rome, found a tuning fork cooling curve similar to that shown in figure 3. He has also found by calculation that in the case of the above mentioned standard tuning fork the coefficient α' of the equation of the curve

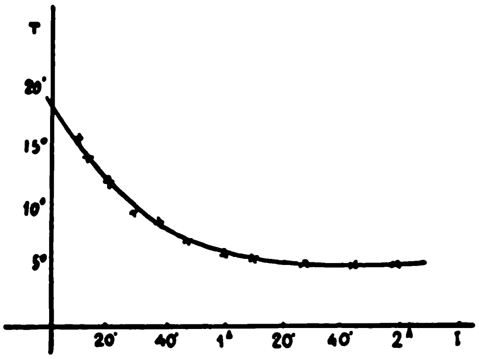

FIG. 3.

$$T = T_a - T_e \cdot e^{\alpha' T}$$

was given by :

$$\alpha' = 0.02339$$

where T and T_a were, respectively, the tuning fork temperature at the instant t and the temperature of the air, and T^e represented the excess of the initial temperature of the tuning fork over that of the temperature of the air.

(*) *Proc. Roy. Soc. of London*, p. 240, May, 1923.

By the method we have developed we can obtain the calibration of a tuning fork very simply and quickly. In figure 4 is shown the stator winding of a small Siemens 100-toothed alternator of the induction type connected in series with the secondary of the transformer in the output circuit of the multivibrator amplifier. This alternator is driven by a d. c. motor which carries on the same shaft a small d. c. generator. In order to obtain a steadier speed of the revolving gear this generator can be loaded with a resistance coil of a suitable value. Moreover, a centrifugal speed regulator of the type used in the Hughes telegraphic apparatus is used on the revolving shaft for the same purpose. In order to obtain a frequency from the alternator as near as possible to the tuning fork frequency, a stroboscopic figure composed of 39 sectors is drawn on the alternator rotor and is observed through a small window, open at each semi-vibration, by an auxiliary electrically-driven tuning fork having a frequency of 200 cycles per second.

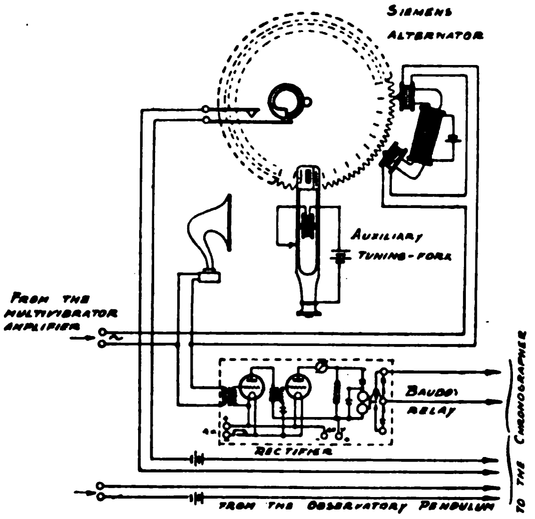

FIG. 4.

Circuit Diagram of the Method Adopted for the Calibration of the Multivibrator Tuning Fork.

When the stroboscopic figure appears still as viewed through the small window, the number of revolutions per second n attained by the alternator is such that the following relation exists :

$$\frac{1''}{39 \times n} = \frac{1''}{200 \times 2}$$

As the rotor has 100 teeth the corresponding frequency of the above conditions is given by :

$$f = \frac{400}{39} \times 100 = 1025.6$$

which is very near to the frequency of the tuning fork.

When the alternator frequency is close to the tuning fork frequency, beats will be heard in the loud speaker telephone in series with the amplifier output transformer of the multivibrator and the Siemens alternator. A suitable amplifier followed by a vacuum-tube detector shunts the loud speaker. In the plate circuit of the detector we have placed a very sensitive Baudot relay, having coils with 11,500 turns each, and a resistance of 5000 ohms per coil. This relay is operated at each beat.

The installation shown in figure 5 is completed by a three-pen recorder. One of the pens is actuated by the above-mentioned relay; the second is actuated by a contact which closes every 10 revolutions of the motor-alternator shaft, and the third is controlled by a contact on the standard pendulum in the Astronomic Observatory of the Campidoglio, which is received by means of a special line. Figure 6 shows one of the records obtained. Dots (a) show the number of beats, the dashes (b) indicate the time intervals (a one-second dash each two seconds), and dots (c) furnish the number of tens of the alternator revolutions, that is, the number of thousand cycles of the alternator current.

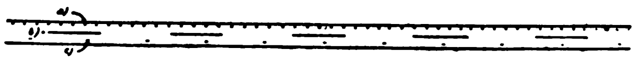

FIG. 6.

We have found that the alternator speed need not be kept absolutely constant during the measurement, and that it is not necessary to observe the stroboscope continuously. Conditions are satisfactory for measurements when the difference between the alternator and the tuning fork frequencies remains the same as indicated by the note in the loud speaker. This condition is ordinarily obtained when beats are not too fast to be recorded. By means of the loud speaker it is possible to control at each instant the regular working of the beat recorder relay.

If small variations of the alternator speed are required, they can be obtained by means of the d. c. generator loading resistance or directly by changing the mechanical regulating mechanism.

Evidently, if n is the number of the alternator cycles in a certain time t, and a is the number of beats recorded in the same time, the tuning fork frequency will be given by $n \pm a/t$. The sign to be applied at a can be obtained by observing the stroboscopic figure corresponding to zero beat. In the case of the Institute installation, at zero beat the stroboscopic figure appeared to revolve slowly in the direction of the shaft revolution. As the same figure normally had a greater speed in the same direction for the ordinary frequencies we came to the conclusion that the sign of a was negative.

Using a temperature controlled box (thermostat) we were able to obtain the calibration of the Institute tuning forks at various temperatures, and thus it was possible to obtain the temperature coefficient, which was 0.105 part in 1000. This is very near to that of 0.12 part in 1000 stated by the tuning fork manufacturer. Such a coefficient may be used for ordinary calibration in which case the tuning fork frequency can be calculated by means of the formula :

$$N = 1026.7 \times (1 - 0.000102\,t)$$

where t is the tuning fork temperature (Centigrade scale) that may be deduced from the air temperature by introducing proper corrections, and 1026.7 is the number of vibrations reduced to zero obtained from a long series of tests.

Using the above mentioned formula it is necessary to keep in mind that besides the uncertainty existing in the value of t, there is another source of error by assuming the quantity $N_0 = 1026.7$ as a constant. This is because the supply current in the tuning fork circuit can change in the intervals between the various measurements, causing other differences of several parts in 100,000 from one test to another. This is especially true when the tests are made on different days. Consequently, when a high precision is required the tuning fork calibration must be repeated for each measurement.

Table I, which refers to measurements made on March 15, 1928 at a mean air temperature of 19 deg. C gives a clear demonstration of the precision of the present method.

TABLE I.

Calibration of the Tuning Fork.

No.	DATE.	Temperature.	Seconds.	Alternator cycles n.	Beats Total number a.	Tuning fork cycles $N = n - a$.	Tuning fork frequency $f = \frac{n - a}{t}$	Mean frequency.	Jumps from the mean %.
1	4 March 1928.	19° C.	104	107.000	437	106.563	1,024,644	1,024,698	— 0.054
2			566	583.435	3469	579.966	1,024,674		— 0.024
3			326	335.610	1551	334.059	1,024,720		+ 0.022
4			488	502.733	2665	500.068	1,024,720		+ 0.022
5			1366	1,408.716	8951	1,399.765	1,024,720		+ 0.022

The principal advantages of the method described are the following :

(1) It permits the tuning fork calibration both before and after the various series of measurements, that is, under conditions which are practically the same as those existing during the use of the tuning fork as an exciter of the multivibrator.

(2) It avoids the necessity of obtaining an absolutely constant speed of the alternator.

In order to demonstrate the method followed during the measurements and the degree of pre-

TABLE II

Calibration of the Piezo-electric Crystal No. 1

March 15th, 1928

$t = 14$ deg. C. Measured tuning fork frequency : $f = 1025.20$

Number of the observations	Reading of the heterodyne condenser for the harmonics		Reading of the heterodyne condenser at zero beats with the crystal frequency	Interpolation frequency
	71st	70th		
Means of 5 observations	822.96	987.98	840.3	71st harmonic 72789.75 70th harmonic 71764.65 Crystal frequency 72682.10

March 18th, 1928

$t = 13$ deg. C. Measured tuning fork frequency : $f = 1025.42$

Means of 7 observations	807.76	973.70	827 36	71st harmonic 72804.8 70th harmonic 71779.4 Crystal frequency 72683.6
Means of 16 observations	808.41	973.79	827.76	71st harmonic 72804.8 70th harmonic 71779.4 Crystal frequency 72685.2

TABLE III

Measurement of the Frequency Emitted by Torrenova (Roma) Electron Tube Transmitter

March 17th 1928

$t = 13$ deg. C. Measured tuning fork frequency : $f = 1025.22$

Number of the observations	Readings of the heterodyne condenser for the harmonics		Readings of the heterodyne condenser at zero beats with the Torrenova frequency	Interpolation frequency	Wavelength (for V = 299 82.10^6 m)
	98th	97th			
I Series			Mean of 8 observations : 920	97th harmonic 99446.34 97th harmonic 100471.06 Torrenova freq. 100240.78	m 2290.8
1	906.0	967 8			
2	906.0	967.8			
3	906 0	967.9			
Mean	906 0	967.8			
II Series			Mean of 11 observations : 920.84	Torrenova freq. 100235.06	m 2991.2
1	906.7	968 0			
2	906.5	967.8			
3	906 6	968.1			
Mean	906.6	968.0			
III Series			Mean of 15 observations : 920.97	Torrenova freq. 100238.06	m 2991.0
1	907.0	968 3			
2	906.9	968.2			
3	907.0	968 4			
Mean	906 97	968.3			
IV Series			Mean of 27 observations : 920.76	Torrenova freq. 100207.5	m 2990.5
1	907.5	969 5			
2	908.0	969 6			
3	907 8	969.5			
Mean	907.8	969.5			

cision obtainable, we give the following two examples :

(1) The calibration of a piezo-electric crystal (Table II).

(2) The measurement of the frequency emitted by a tube transmitting set of the Rome (Torrenova) high power radio installation (Table III).

The general mean value of the three series of measurements made on March 15 and 18, 1928, gives 72684.5 as the crystal frequency. This value, at a temperature of about 13.5 deg. C differs by + 3.44 parts in 100,00 from the value 72682 determined on December 12, 1927 by the Naval Radio Laboratory in Leghorn at a temperature of 14.8 deg. C, but using a different method.

It can be seen that the sign of the frequency difference is in accord with the temperature difference, so there is a perfect agreement between Rome and Leghorn measurements.

The control installation is completed by a series of five standard piezo-electric crystals calibrated as described above.

We believe that very quick determinations over a wide range of frequencies can be easily made by utilizing the oscillations and the harmonics produced by the above mentioned crystals together with an electron tube generator.

By means of the methods and apparatus described above the Experimental Institute of Communications is now in a position to make frequency measurements of distant radio transmitting stations with accuracy and precision and to exercise, as required, the necessary control of the waves of radio transmitting stations.

RADIOTELEGRAPHIC DETERMINATION OF LONGITUDE

by M. HASIMOTO.

1. **Introduction.** — A resolution to fix a longitude net by observation of Radio Time Signals, was made in 1922 at the Congress of the International Astronomical Union which met at Rome, and the details of method and arrangement were discussed at the meeting of the International Union of Geodesy and Geophysics at Madrid in 1924 and that of the Astronomical Union at Cambridge in 1925.

To carry out the scheme, rhythmic signals were broadcasted from eight stations during October and November 1926, and those from Nauen were also available to the same purpose.

The astronomical observatory or station with proper equipment, which would cooperate as first class, has to receive Time Signals from two different groups of radio-stations at least, to get relations between stations, the longitude difference of which is more than 8 hours on both sides of it, while the second class station has to link it with a principal station by means of some of the time signals.

It was reported that 21 observatories joined as the first class and about 20 as the second class.

The Tokyo Astronomical Observatory joined the service as the first class, and tried to receive the radio signals as many as possible, to secure the best result for the longitude differences.

The astronomical observation for clock correction was carried out twice a day in every clear morning and evening, with an easy reversible type transit instrument made by Bamberg's Work in Berlin and another from Prin in Paris. A meridian circle made by Gautier in Paris was also used in the evening, but the result did not agree with those of the smaller instruments. The astronomical clock Riefler N° 358 was used as a time piece.

2. **Reception of Radio Signals.** — We succeeded in registering 6 stations with long wave, and an operator succeeded to obtain the impressions of Annapolis in the latter half of November, in spite of the very powerful interferences of Kahuku at Hawaii Island.

Short notes about individual station are as follows :

BORDEAUX. The signals at 8h G. M. T. were very weak during October and atmospheric disturbances very strong, but towards the end of November, the intensity of signals increased and the reception became rather easy, but the impression was not good.

The signals at 20h G.M.T. were generally strong and good.

Saigon. The signals were very strong and almost free from disturbances.

Honolulu. *a*) It was generally easy to receive the signals, but towards the end of November, that at 20h 30m G.M.T. suffered from atmospheric disturbances and the record was missed several times.

b) Signals with 37 metres at 10h 40m G.M.T. were not impossible to receive, but were sacrificed to get the signals from Malabar, as it was thought that we can get a better result by receiving signals from as many stations as possible.

Malabar. The signal intensity was pretty strong but it was sometimes disturbed by the messages of nearer stations and made difficult to record.

Annapolis. The wave length of this station is so near to that of Kahuku, that it was almost hopeless to receive Annapolis as long as Kahuku is in action. Fortunately impressions of the signals at 3h 10m and 10h 10m were obtained, which, in spite of very bad definition of the records, will be of great service in adjusting the value of longitude.

Nauen. The signals were pretty strong during the season.

TABLE I. — List of Radio Stations.

STATION	WAVE LENGTH in metre	G.M.T. OF EMISSION	NUMBER OF RECORDS TAKEN AT TOKYO	
			October	November
Bordeaux	18900	8^{h} 1^{m} — 8^{h} 6^{m}	8	19
		20 1 — 20 6	31	29
Issy	32	8 1 — 8 6	—	—
		20 1 — 20 6	—	—
Eiffel Tower	2650	9 30 — 9 36	—	—
		22 30 — 22 36	—	—
Saigon	15800	about 11 30	30	26
		id. 19 0	31	26
Annapolis	17145	3 10 — 3 15	—	3
		10 10 — 10 15	—	14
		20 10 — 20 15	—	—
Bellevue	25 and 75	3 20 — 3 25	—	—
		10 20 — 10 25	—	—
		20 20 — 20 25	—	—
Honolulu	11500	3 30 — 3 35	31	29
		10 30 — 10 35	30	30
		20 30 — 20 35	31	23
Id.	37	3 40 — 3 45	—	—
		10 40 — 10 45	—	1
		20 40 — 20 45	—	—
Malabar	15600	10 40 — 10 45	26	25
Nauen.	18000	12 1 — 12 6	30	28

3. Reduction of Longitude of the Tokyo Astronomical Observatory. — At present, the times of radio signals at Greenwich, Paris, Potsdam, Washington, San Diego, Ottawa, and Vancouver are available for reduction of the longitude of Tokyo. Taking differences between the local times of observations, I got the values in the table II.

TABLE II. — Longitude Difference.

TOKYO — PARIS

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$8^h\ 1^m$ 20 1 Total	— — $+ 85^\circ 47$	54 116 170	$9^h 18^m 10^s 1806$ 10 1710 10 1740	$\pm 0^s 0305$ $\pm$ 0 0326 —	— — $+ 0^s 0014$
Annapolis . . .	17145	10 10	+ 43 25	18	10 1319	± 0 0342	— 0 0202
Saigon	15800	19 0	— 52 32	78	10 1060	± 0 0327	+ 0 0003

Adjusted Longitude . . . . $9^h 18^m 10^s 1311$

Time required by radio wave to traverse 10 degrees of great circle arc. 0.00485

Transmission Time round the Earth . . . 0.175

POTSDAM — TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$8^h\ 1^m$ 20 1 Total	— — $+ 80^\circ 03$	52 122 174	$9^h 18^m 10^s 1331$ 10 1235 10 1264	$\pm 0^s 0249$ $\pm$ 0 0330 —	— — $- 0^s 0008$
Nauen	18000	12 1	+ 79 96	118	10 1279	± 0 0292	+ 0 0008

Adjusted longitude . . . . $9^h 18^m 10^s 0916$

Transmission Time round the Earth . . . (0 160) (*)

(*) Mean of values from Paris-Tokyo, Washington-Tokyo, and Washington-Greenwich.

WASHINGTON — TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux. . . .	18900	8^h 1^m	—	50	14^{h}26^{m}25^{s}8829	± 0^{s}0302	—
		20 1	—	108	25 8745	± 0 0276	—
		Total	+ 36°94	158	25 8771	—	+ 0^{s}0015
Annapolis. . . .	17145	3 10	—	5	25 8934	—	—
		10 10	—	25	25 8956	—	—
		Total	+ 97°79	30	25 8952	± 0 0417	— 0 0036
Honolulu. . . .	11500	3 30	—	4	25 8395	—	—
		10 30	—	58	25 8550	—	—
		Total	— 14°10	62	25 8540	± 0 0338	— 0 0021

Adjusted Longitude	14^{h}26^{m}25^{s}8615
Time required to traverse 10 degrees arc. . .	0.00382
Transmission Time round the Earth	0.137

SAN DIEGO - TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux. . . .	18900	8^h 1^m	—	38 (14	17^h 6^{m}58^{s}4924 58 516)	± 0^{s}0388 by ear.	—
		Total	+ 8°52	38	58 4924	—	+ 0^{s}0071
Annapolis. . . .	17145	3 10	—	5	58 4770	—	—
		10 10	—	25	58 5107	—	—
		Total	+ 64°94	30	58 5048	± 0 0395	+ 0 0007
Honolulu. . . .	11500	3 30	—	116	58 4876	± 0 0283	—
		10 30	—	116	58 4883	± 0 0285	—
		20 30	—	96	58 4867	± 0 0245	—
		Total	+ 18°06	328	58 4876	—	— 0 0008
Saigon.	15800	19 0	— 80°84	103	58 4559	± 0 0265	+ 0 0006
Malabar	15600	10 40	— 79°02	59	58 4544	± 0 0254	— 0 0016

Adjusted Longitude	17^h 6^{m}58^{s}4824
Time required to traverse 10 degrees arc. . .	0.00335
Transmission Time round the Earth	0.121

GREENWICH — TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$20^h\ 1^m$	+ 85°17	112	$9^h18^m10^s1480$	± 0^s0303	— 0^s0009
Nauen	18000	12 1	+ 72 24	98	10 1448	± 0 0293	+ 0 0015
Annapolis . . .	17145	10 10	+ 45 55	11	10 1256	± 0 0361	— 0 0061

Adjusted Longitude . . . . $9^h18^m10^s1111$

Transmission Time round the Earth . . (0.160).

OTTAWA — TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M E. of Single Comp.	Residual.
Bordeaux . . .	18900	$8^h\ 1^m$	—	54	$14^h21^m\ 2^s0681$	± 0^s0295	—
		20 1	—	120	2 0503	± 0 0347	—
		Total	+ 41°07	174	2 0559	—	+ 0^s0040
Nauen	18000	12 1	+ 25 42	112	2 0295	± 0 0374	— 0 0089
Annapolis . . .	17145	3 10	—	5	2 0908	—	—
		10 10	—	25	2 0980	—	—
		Total	+ 91 85	30	2 0968	± 0 0339	+ 0 0011
Honolulu . . .	11500	3 30	—	43	1 9976	± 0 0489	—
		10 30	—	90	2 0184	± 0 0387	—
		20 30	—	38	1 9882	± 0 0418	—
		Total	— 13 85	171	2 0064	—	+ 0 0019

Adjusted Longitude . . . . $14^h21^m\ 2^s0165$

Time required to traverse 10 degrees Arc. 0.00863

Transmission Time round the Earth. . . 0.311.

VANCOUVER — TOKYO

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	8^h 1^m	—	26	$17^h 30^m 38^s$ 4371	± 0^s 0116	—
		20 1	—	14	38 4539	± 0 0265	—
		Total	+ 17°95	40	38 4430	—	— 0 0185
Annapolis . . .	17145	10 10	+ 63 83	13	38 4774	± 0 0427	— 0 0101
Honolulu . . .	11500	3 30	—	67	38 4697	± 0 0401	—
		10 30	—	67	38 4731	± 0 0368	—
		20 30	—	57	38 4537	± 0 0494	—
		Total	+ 16 99	191	38 4661	—	+ 0 0051
Saigon	15800	11 30	—	54	38 4174	± 0 0313	—
		19 0	—	32	38 3985	± 0477	—
		Total	— 67 45	86	38 4104	—	— 0 0010

Ajusted Longitude	$19^h 30^m 38^s$ 4510
Time required to traverse 10 degrees arc .	0.00587
Transmission Time round the Earth . . .	0.211

GREENWICH — WASHINGTON

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	20^h 1^m	+ 48°23	102	5^h $8^m 15^s$ 7277	± 0^s 0197	—
Annapolis . . .	17145	10 10	—	92	15 7715	± 0 0246	—
		20 10	—	96	15 7778	± 0 0217	—
		Total	— 52 24	188	15 7747	—	—

Adjuted Longitude	5^h $8^m 15^s$ 7503
Time required to traverse 10 degrees arc .	0.00468
Transmission Time round the Earth . . .	0.168

GREENWICH — OTTAWA

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$20^h\ 1^m$	— 44°10	114	$5^h\ 2^m51^s9043$	± 0^s0233	+ 0^s0080
Nauen	18000	12 1	— 46 81	96	51 8851	± 0 0307	— 0 0092
Annapolis . . .	17145	10 10	—	94	51 9371	± 0 0274	—
		20 10	—	96	51 9651	± 0 0261	—
		Total	+ 46 30	190	51 9611	—	— 0 0002

Adjusted Longitude . . . . $5^h\ 2^m51^s9280$

Time required to traverse 10 degrees arc. 0.00719

Transmission Time round the Earth . . 0.259

GREENWICH — PARIS (Correction to the Longitude in use).

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$20^h\ 1^m$	+ 0°03	108	— 0^s0244	± 0^s0266	— 0^s0025
Annapolis . . .	17145	10 10	—	63	— 0 0115	± 0 0309	—
		20 10	—	64	— 0 0163	± 0 0253	—
		Total	— 2 47	127	— 0 0139	—	+ 0 0069
Eiffel Tower . .	2650	9 31	—	99	— 0 0257	± 0 0256	—
		22 31	—	116	— 0 0260	± 0 0256	—
		Total	+ 2 97	215	— 0 0259	—	— 0 0029

Adjusted Correction . . . . — 0^s0219

POTSDAM — GREENWICH (Correction to the Longitude in use).

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	$20^h\ 1^m$	— 5°14	114	+ 0^s0233	± 0^s0207	+ 0^s0002
Nauen . . .	18000	12 1	+ 7 73	100	+ 0 0180	± 0 0218	— 0 0003

Adjusted Correction . . . . + 0^s0212

VANCOUVER — WASHINGTON

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp.	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux . . .	18900	8^h 1^m	—	54	3^h 4^{m}12^{s}5636	—	—
		20 1	—	14	12 5642	—	—
		Total	— 19°00	68	12 5637	± 0^{s}0368	— 0^{s}0292
Annapolis . . .	17145	3 10	—	50	12 5922	± 0 0351	—
		10 10	—	56	12 5930	± 0 0297	—
		20 10	—	58	12 5890	± 0 0381	—
		Total	— 33 96	164	12 5913	—	+ 0 0052
Bellevue. . . .	75	3 20	—	42	12 5938	± 0 0482	—
		10 20	—	60	12 5955	± 0 0318	—
		Total	— 33 96	102	12 5948	—	+ 0 0083
Honolulu . . .	11500	3 30	—	2	12 5555	—	—
		10 30	—	28	12 6225	—	—
		Total	+ 31 09	30	12 6180	± 0 0414	+ 0 0024
Id. . . .	37	3 40	—	6	12 6128	—	—
		10 40	—	22	12 6180	—	—
		Total	+ 31 09	28	12 6234	± 0 0446	+ 0 0082

Adjusted Longitude	3^{h}4^{m}12^{s}6015	
Time required to traverse 10 degrees arc.	0 00454	long wave
	0 00440	short wave
Transmission Time round the Earth . .	0 163	long wave
	0 158	short wave

SAN DIEGO — WASHINGTON

RADIO STATION	Wave length in metre.	G. M. T.	Difference of Distances.	Num. of comp. (*)	Longitude Difference.	M. E. of Single Comp.	Residual.
Bordeaux. . . .	18900	8^h 1^m	— 28°42	28	2^{h}40^{m}32^s 6120	± 0^s 0266	— 0^s 0015
Annapolis. . . .	17145	2 55	—	58	32 6107	± 0 0241	—
		3 10	—	60	32 6097	± 0 0237	—
		10 10	—	55	32 6115	± 0 0229	—
		20 10	—	52	32 6081	± 0 0250	—
		Total					
Bellevue	75	3 20	—	43	32 6289	± 0 0221	—
		10 20	—	43	32 6286	± 0 0255	—
		Total	— 32 86	370	32 6113	—	0 0000
Honolulu. . . .	11500	3 30	—	2	32 6560	—	—
		10 30	—	29	32 6426	—	—
		Total	+ 32 13	31	32 6434	± 0 0219	0 0000

Adjusted Longitude	2^{h}40^{m}32^s 6275
Time required to traverse 10 degrees arc . . .	0 00494
Transmission Time round the Earth.	0 178

(*) Mean of 1st and 306th signals is taken for comparison.

I assume the following coordinates for astronominal observatories.

TABLE III.

OBSERVATORY	LONGITUDE	LATITUDE
Greenwich. . . .	0° 0′ 0″	+ 51°28′38″
Paris.	2 20 14 E	+ 48 50 11
Potsdam	13 3 58 E	+ 52 22 56
Washington . . .	77 3 57 W	+ 38 55 14
San Diego	117 12 6 W	+ 32 42 26
Ottawa	75 43 0 W	+ 45 23 29
Vancouver. . . .	123 7 W	+ 48 31
Tokyo	139 32 30 E	+ 35 40 21

And for radio stations.

TABLE IV.

RADIO STATION	LONGITUDE		LATITUDE
Bordeaux	0°48′	W	+ 44°42′
Saigon	106 42	E	+ 10 47
Nauen	12 55	E	+ 52 39
Malabar	107 36	E	— 6 56
Annapolis	76 27	W	+ 38 59 25″
Honolulu	157 58	W	+ 21 21 45
Eiffel Tower . . .	2 17 44″E		+ 48 51 30

In the present state of things, we can safely take the Earth as a sphere; so I got the following distances between the stations, in degrees of great circle arc.

TABLE V.

OBSERVATORY.	Bordeaux.	Saigon.	Annapolis.	Nauen.	Honolulu.	Malabar.	Eiffel Tower.
Greenwich . .	64°7′9	—	52°43′4	8° 1′0	—	—	3°0′2
Paris	6 30.0	91° 7′2	55 1.8	7 41.6	—	—	0 2.1
Potsdam . . .	11 56.1	—	—	0 17.0	—	—	—
Washington . .	55 1.5	—	0 29.0	—	69°55′4	—	—
San Diego . .	83 26.8	119 38.1	33 20.4	—	37 47.4	131°8′5	—
Ottawa. . . .	50 54.0	—	6 25.6	54 49.2	69 40.5	—	—
Vancouver . .	74 1.4	106 14.5	34 26.7	—	38 49.8	—	—
Tokyo. . . .	91 58.1	38 47.7	98 16.6	80 14.3	55 49.4	52 7.6	—

4. Adjustment of the Longitude Differences. — As we can easily see by inspecting Table II, the value of longitude varies as the difference of distances from radio stations. To solve it by the least square method, I take $\Delta\lambda + a\,S_{10} = w$, as the form of the equation of condition. Where, $\Delta\lambda$ is correction to assumed value to get longitude difference free from distance of radio stations S_{10} is the difference of distances in unit of 10 degrees of great circle arc, a is a constant which shows time wanted by radio wave to traverse 10 degrees of great circle arc, and w is the observed value minus the assumed value.

The solutions are given in the Table II, the residuals (observed minus computed) are pretty small.

The following remarks should be made as regards the value of $a \times 36$ i.e. the time wanted by radio wave to go round the Earth.

1. San Diego-Tokyo : « too small ». It seems that the correction due to lag applied to the times for Saigon and Malabar at San Diego is too large.

2. Vancouver-Tokyo and Ottawa-Tokyo. « Too large. » It seems that fainter signals were heard too late, at Ottawa and Vancouver.

3. From the experiments of Abraham, Dufour and Ferrié in 1912 and 1913, with galvanometer, and those on short wave echoes at Geltow, and the studies of high-frequency radio wave propagation made by Taylor and Young at Bellevue, 1928, it is highly probable that the quic-

kest time of arrival of radio wave round the Earth is near $0^{s}140$. From the present observation with ink recorder, it comes out to be very near $0^{s}160$. To explain this discrepancy, I dare to take an analogy of earthquake wave through the earth crust, where maximum movement follows sometime after 'S'phase; and in the case of thunder storm, we hear the loudest sound soon after the first shock.

It seems to me that the radio wave which is strong enough to move the recorder, follows some time after the first tremor, which is however quite sufficient to move a very sensitive galvanometer.

5. Lag of Time in Recorder. — The lag of time in the receiving set at Tokyo, i.e. time between the arrival of wave at antenna and recording of signal, was not yet taken into accounti Mr M. Miyadi, an engineer in Mitaka Time Station, carried out experiment on it, and proved that the lag lies between $0^{s}009$ and $0^{s}016$, and varies with the final current at the recorder; the smaller the lag, the larger the current, and independent of incident wave length. By this experiment, we can guess that the actual lag during the longitude observation to be a figure something like $0^{s}013$, while the personal equation on time observation, which lies between $0^{s}01$ and $0^{s}02$, remains unknown at present. I therefore postpone to introduce definite correction for lag of time till more exact determination is made in the future.

6. Longitude of Tokyo. — As final result, I have :

TABLE VI

ROUTE	LONGITUDE OF TOKYO East of Greenwich.
Tokyo—Greenwich	$9^{h}18^{m}10^{s}1111$
Tokyo—Potsdam—Greenwich . . .	10 1128
Tokyo—Paris—Greenwich	10 1092
Tokyo—Washington—Greenwich . .	10 1112
Tokyo — San-Diego — Washington — Greenwich	10 1046
Tokyo — Vancouver — Washington — Greenwich.	10 0992
Tokyo—Ottawa—Greenwich	10 0885

Rejecting the last two values through Ottawa or Vancouver, where the signals were observed by ear, and might contain some unknown equation due to hearing, affecting the value of longitude, and taking the mean of the first 5, the longitude of the Tokyo Astronomical Observatory at Mitaka nr. Tokyo comes out to be

$9^{h}18^{m}10^{s}111$ East of Greenwich.

Applying the correction of time lag and rounding, Tokyo is

$9^{h}18^{m}10^{s}10$ East of Greenwich.

July 1928.
Tokyo Astronomical Observatory.

LES RETARDS A L'ENREGISTREMENT DES SIGNAUX HORAIRES RADIOTELEGRAPHIQUES

(Mesures effectuées sur le dispositif d'enregistrement du Bureau International de l'Heure à l'Observatoire de Paris)

par M. R. JOUAUST

Avertissement. — Le travail ci-dessous a été effectué à l'occasion de l'opération mondiale de détermination de longitudes et n'avait d'autre but que de dissiper les appréhensions de certains astronomes relativement à la précision de la méthode de détermination de l'heure par enregistrement de signaux radiotélégraphiques.

Certains résultats expérimentaux nous ayant paru susceptibles d'intéresser les radiotélégraphistes, nous avons cru devoir le communiquer à l'U. R. S. I. mais nous l'avons laissé dans la forme où il a été présenté à l'Assemblée générale de l'Union Internationale Astronomique.

Il ne faut pas perdre de vue que ce travail a été rédigé surtout pour des astronomes ce qui explique la forme très élémentaire donnée à l'explication du fonctionnement des appareils radiotélégraphiques.

Certains des phénomènes mis en évidence semblent mériter une étude plus complète et des expériences complémentaires que nous nous proposons d'exécuter par la suite.

⁂

L'opération mondiale de détermination des longitudes exécutée en octobre et novembre 1926 semblait se prêter à une mesure de la vitesse de propagation des ondes radiotélégraphiques et, en effet, les astronomes chargés du dépouillement des observations n'ont pas manqué d'évaluer cette vitesse (*).

Les résultats ont été assez surprenants. Les vitesses trouvées ont été nettement inférieures à la vitesse de la lumière et les différences sont telles qu'elles sont assez difficilement explicables avec les idées actuelles sur le mécanisme de propagation des ondes.

On pouvait se demander dans ces conditions si les faibles valeurs trouvées n'étaient pas dûes à une erreur systématique et en particulier si, comme l'a supposé M. Lambert, le retard à l'*enregistrement* des signaux radiotélégraphiques n'était pas plus élevé pour les signaux faibles (provenant de postes éloignés) que par des signaux forts (postes rapprochés).

Telles sont les considérations qui nous ont amenés à entreprendre sur le dispositif d'enregistrement des signaux horaires installé au Bureau International de l'Heure ces mesures dont nous allons parler.

Il importe tout d'abord de décrire sommairement l'installation radiotélégraphique.

Les ondes radiotélégraphiques captées par un cadre sont amplifiées tout d'abord par un amplificateur haute fréquence à transformateurs, la différence de potentiel amplifiée est appliquée entre le filament et la grille d'une lampe dont la plaque est alimentée par un courant de haute fréquence de période légèrement différente de celle des signaux reçus. Il en résulte la production dans la plaque de cette lampe d'un courant de fréquence musicale qui subit dans l'amplificateur même une première amplification à fréquence musicale au moyen d'une dernière lampe couplée par transformateur non accordé à l'avant-dernière. Le courant de fréquence musicale sortant de ce premier amplificateur que nous désignerons par la lettre Z est envoyé dans un deuxième amplificateur M_1. Cet appareil est du type amplificateur à basse fréquence à transformateurs. Mais il présente cette particularité que deux des transformateurs de liaison présentent un entrefer réglable. Comme en outre des condensateurs sont placés en dérivation sur les enroulements de ces transformateurs, ceux-ci peuvent être accordés sur une fréquence musicale déterminée et l'amplificateur se montre excessivement sélectif. Les signaux sortant de l'amplificateur M_1 sont envoyés dans un troisième amplificateur M_2 comportant deux lampes couplées par résistance : une lampe détectrice utilisant le procédé du condensateur shunté, et une dernière lampe donnant une amplification à courant continu. Cette lampe est couplée à la lampe détectrice par une résistance shuntée au moyen d'un condensateur de l'ordre du microfarad. C'est dans la plaque de cette dernière lampe que se trouvent les enroulements des oscillographes Abraham dont le déplacement du style s'enregistre sur une bande de papier enfumé.

Nous n'insisterons pas sur la description de ces oscillographes qui sont une modification de l'appareil bien connu de Marcel Deprez et qui ont été décrits dans plusieurs publications.

Le mécanisme d'enregistrement des signaux est donc le suivant :

Le courant de haute fréquence transformé en courant de fréquence musicale dans l'amplificateur Z et fortement amplifié par l'amplificateur M_1 et les deux premières lampes de M_2, est transformé en courant continu par la lampe détectrice de M_2.

Autrement dit, pendant toute la durée du signal, le courant continu permanent filament-plaque de la détectrice subit une variation provoquant elle-même une variation du courant filament-plaque du dernier étage à courant continu. Il en résulte que ce courant traversant les enroulements des enregistreurs, le style de ceux-ci est dévié pendant toute la durée du signal.

(*) Littal, Transactions of the American Geophysical Union. (*Bulletin of the National Research Council*, n° 61, p. 50.)

— Lambert, *Comptes rendus de l'Académie des Sciences*, 1928.

Au Bureau International de l'Heure, on prend le moment où le style commence à dévier pour caractériser l'instant du signal. Certains observateurs avaient proposé d'utiliser au contraire l'instant du milieu de la déviation. Nous verrons tout à l'heure que cette manière d'agir peut conduire à de grosses erreurs.

Le problème qui se posait pour nous était donc le suivant : Existe-t-il un retard entre l'instant où les ondes frappent le collecteur aérien et celui où l'enregistreur commence à dévier, quelle est son importance, est-il variable avec l'intensité des signaux reçus?

Théoriquement ce retard doit exister et quelques considérations sur le mécanisme de la détection permettent facilement de s'en rendre compte :

Comme il a été dit, l'appareil enregistreur du B. I. H. utilise pour la transformation du courant de fréquence musicale en courant continu le phénomène de détection par la grille. Le conducteur reliant au filament la grille de la lampe détectrice est coupé par un condensateur de l'ordre du millième de microfarad shunté par une résistance de plusieurs mégohms. Lorsqu'une différence de potentiel alternative est appliquée entre filament et grille, et lorsque l'alternance rend la grille positive, celle-ci absorbe quelques électrons qui chargent le condensateur. Le potentiel de la grille s'abaisse. Pendant l'alternance suivante, le condensateur tend à se décharger à travers la résistance qui le shunte, mais étant donnée la valeur élevée de celle-ci, la décharge n'est pas complète et au moment de l'alternance positive suivante, la grille a conservé un potentiel un peu plus faible que sa valeur primitive.

Cette troisième alternance donne une nouvelle charge négative au condensateur, le potentiel de grille s'abaisse à une valeur plus faible qu'après la première alternance et le processus continue jusqu'à ce que le potentiel de grille ait atteint une valeur négative telle que la quantité d'électricité perdue par le condensateur par décharge à travers la résistance pendant les alternances négatives, soit égale à la quantité d'électricité apportée par les électrons pendant l'alternance positive. D'autre part, chaque abaissement du potentiel de grille entraîne une diminution du courant plaque par rapport à sa valeur de régime, variation qui prend une valeur fixe quand le potentiel de régime est lui-même fixé.

Comme on le voit, un certain temps est nécessaire pour que les valeurs de régime soient atteintes. On s'en rend très bien compte sur les enregistrements par ce fait que la déviation du style est progressive. Mais dans le cas actuel, ce qui nous intéresse c'est le temps nécessaire pour que le potentiel de la grille atteigne une valeur telle que le courant plaque de la lampe détectrice commence à diminuer. A priori, il semble que cette diminution doive commencer dès la première alternance rendant la grille positive. En réalité un autre phénomène, la détection par la plaque, vient se superposer à la détection par la grille.

Nous avons dit que le potentiel de la grille s'abaissait, en réalité c'est la valeur moyenne de ce potentiel qui s'abaisse, mais le potentiel grille subit par rapport à ce potentiel moyen des variations alternatives de fréquence égale à celle des oscillations de fréquence musicale qu'on cherche à détecter.

Les alternances positives ont donc tendance à augmenter le courant plaque, les alternances négatives à le diminuer mais par suite de la courbure des caractéristiques des lampes les diminutions sont inférieures aux augmentations, le courant moyen plaque tend à augmenter. C'est ce phénomène qui constitue la détection par la plaque. On voit que cette détection se manifeste par une action sur le courant plaque de sens inverse à la détection par la grille. Ce que nous observons en réalité, c'est la différence des déviations. La détection par la plaque est un phénomène instantané tandis que comme nous l'avons vu, il faut un certain temps pour que la détection par la grille atteigne son effet maximum. Il est donc fort possible qu'au début les deux actions se détruisent, produisant ainsi une apparence de retard sur la détection grille qui est seule utilisée.

Nous allons voir les curieuses complications qu'amène la superposition des deux phénomènes.

Les retards qu'on cherchait à évaluer étant évidemment faibles, il a paru nécessaire pour les mesurer avec précision, d'utiliser un appareil à déroulement plus rapide que les enregistreurs à noir de fumée utilisés en général.

On pourrait à la rigueur augmenter mécaniquement cette vitesse de déroulement, mais un enregistreur photographique a semblé préférable et nous avons utilisé l'oscillographe de Blondel. Nous disposions d'un appareil de ce genre à trois équipages et permettant des enregistrements continus sur bande de papier sensible. Cet appareil avait été mis à la disposition du B. I. H. par le Laboratoire Central d'Électricité.

Les opérations à effectuer semblent à priori fort simples :

Produire un signal au moyen d'un poste local.

Faire circuler le courant détecté sortant des appareils d'enregistrement dans un des équipages de l'oscillographe, un autre équipage étant parcouru par un courant circulant dans un circuit que ferme l'appareil de manœuvre produisant les signaux.

Mais certaines difficultés pratiques se rencontrent lorsqu'on cherche à appliquer ce mode opératoire. Quel que soit le mode de manipulation employé, le poste local n'obéit pas immédiatement. Heureusement de nombreux détails relatifs à la façon dont se produisent les signaux se relèvent très facilement sur le cliché fourni par l'oscillographe et, par leur interprétation, permettent de se rendre compte de l'instant initial de ce signal.

Pareille interprétation n'eût pas été possible avec les enregistrements sur bande enfumée sur lesquels ces détails n'apparaissent pas par suite de la trop grande inertie des appareils.

Le premier procédé de manipulation employé était le suivant : Le circuit grille du poste local émetteur était coupé par une capacité de l'ordre du microfarad shuntée par une résistance de plusieurs mégohms. Dans ces conditions par un mécanisme sur lequel nous n'insisterons pas, car il s'agit d'un montage bien connu, il se produit des émissions rythmées qui, avec les constantes choisies, se reproduisaient à peu près toutes les secondes. L'un des équipages de l'oscillographe était parcouru par le courant plaque des lampes de l'émetteur local, le deuxième était placé à la sortie des appareils récepteurs et le troisième dans un circuit alimenté par le secteur d'éclairage de l'Observatoire. La fréquence du courant de ce secteur étant de 42 périodes par seconde, on avait ainsi sur le cliché une échelle de temps.

La figure 1 représente le relevé obtenu. Nous donnons ci-dessous un dessin schématique dans lequel nous avons exagéré les particularités du cliché pour permettre de suivre plus facilement son interprétation.

Au bas de la figure se trouvent figurées les indications du galvanomètre intercalé dans le courant plaque de l'oscillographe. On voit que ce courant commence à croître au point A. Mais il est à peu près certain que le poste ne commence pas immédiatement à osciller et que la naissance des oscillations correspond au bec du tracé. C'est donc l'instant de B que nous prenons comme début initial de signal. Cette manière de faire est justifiée par ce fait qu'à l'instant B nous voyons de petites oscillations apparaître dans le tracé fourni par l'oscillographe placé à la sortie de l'appareil récepteur.

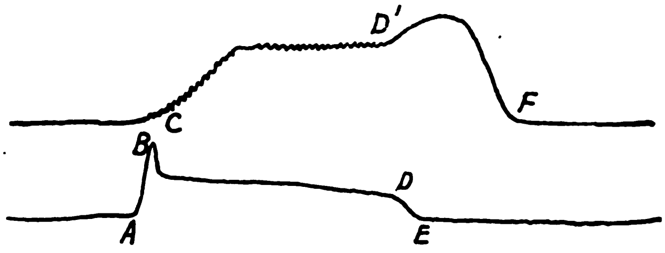

FIG. 1.

La détection n'étant jamais complète, du courant de fréquence musicale peut-être perçu à la sortie de l'appareil amplificateur et c'est ce courant de fréquence musicale qui se traduit par les oscillations que l'on voit dans le tracé relevé à la sortie du système amplificateur. L'apparition de ces oscillations précisément à l'instant B, justifie le choix que nous avons fait de cet instant pour début du signal. On constate que le spot de l'oscillographe placé derrière des amplificateurs ne dévie pas immédiatement mais à l'instant C. C'est le retard à la détection dû au rôle de la capacité, retard dont nous avions envisagé l'existence théorique. En utilisant l'enregistrement du secteur qui figure à la partie supérieure du cliché, nous pouvons évaluer ce retard BC qui est de l'ordre de 2,5 millièmes de seconde.

Plusieurs clichés relevés dans les mêmes conditions ont fourni des résultats identiques.

Le cliché que nous avons reproduit, présente certaines particularités intéressantes au point de vue de l'étude du mécanisme de détection par la grille. L'émetteur auxiliaire cesse évidemment d'osciller en D.

A ce moment du reste les oscillations de fréquence musicale disparaissent du tracé de l'enregistrement mais la déviation du spot du galvanomètre loin de revenir à zéro commence par augmenter et le galvanomètre ne revient à sa position d'équilibre qu'à un instant F bien postérieur à la cessation du signal.

La raison de ces apparences est la suivante .

Le courant détecté qui fait dévier l'oscillographe dans la région CD′ est comme nous l'avons dit, la différence entre l'action détectrice de la courbure inférieure de la caractéristique plaque. Cette dernière action cesse en même temps que le signal. Le condensateur au contraire ne se déchargeant pas immédiatement, puisqu'il est shunté par une résistance très élevée, son action continue à se produire même après la cessation du signal et à l'instant D′ on observe l'action intégrale de la détection grille, tandis que dans la région CD′ on n'observait que cette action diminuée de l'action de la détection plaque. C'est ce qui explique que la déviation du spot de l'oscillographe commence par augmenter au moment où le signal cesse. Ces phénomènes avaient déjà été prévus théoriquement, mais à notre connaissance ils n'avaient jamais été relevés expérimentalement au moins dans les conditions de la pratique.

On voit en tous cas que la durée du signal enregistré est beaucoup plus considérable que la durée réelle du signal. Cette durée apparente dépend de la valeur de la capacité de détection, de la valeur de la résistance qui la shunte (valeur dont la constance ne saurait être assurée, les résistances élevées telles qu'on sait les réaliser ayant toujours tendance à augmenter). *On voit donc que ce serait une grosse erreur de prendre pour instant du signal le milieu de l'enregistrement.*

Dans une autre série d'expériences, on a utilisé pour faire émettre les signaux au poste local le procédé de manipulation utilisé pour les postes à arc. On modifiait la fréquence des oscillations en mettant en court-circuit une partie de l'inductance du circuit oscillant. Le fonctionnement du manipulateur provoquant cette opération amenait en même temps la fermeture d'un circuit et faisait circuler un courant dans l'un des équipages de l'oscillographe.

Les premières expériences exécutées par ce procédé conduisirent à des résultats assez décevants. Les retards mesurés étaient beaucoup plus considérables que ceux obtenus par le premier mode opératoire. Ces retards élevés furent attribués au fait que l'émetteur local n'obéissait pas immédiatement à la commande, c'est-à-dire qu'un certain temps s'écoulait entre le moment où l'inductance était mise en court-circuit et celui où les oscillations atteignaient la fréquence correspondant à la nouvelle valeur de son circuit oscillant, fréquence pour laquelle étaient réglés les divers circuits d'accord du système récepteur. Pour se rendre compte qu'il en était bien ainsi un certain nombre d'expériences furent entreprises. L'amplificateur sélectif pour fréquence musicale M_1 fut supprimé. On supprima également le condensateur dont nous avons fait mention et qui dans l'amplificateur M_2 shunte la résistance de liaison entre la lampe détectrice et la lampe amplificatrice à courant continu. Ce condensateur avait pour effet d'étouffer le courant de fréquence musicale qui passe malgré la détection, de telles sortes que les petites oscillations auxquelles nous avons fait allusion dans l'interprétation du cliché de la figure 1 n'étaient pas toujours très visibles. En opérant comme nous venons de le dire, toute sélection de fréquence musicale étant supprimée, l'accord des circuits haute fréquence se trouvait insuffisant pour empêcher les dispositifs d'enregistrement d'être actionnés aussi bien par l'onde de repos que par l'onde de travail.

On pouvait suivre par l'écoute au téléphone la manipulation de l'émetteur local qui se traduisait par un changement de note, mais les appareils enregistreurs (oscillographe ou style) déviaient dès que l'émetteur local était en fonctionnement. On constatait tout au plus une légère augmentation de cette déviation lorsqu'on passait sur l'onde de travail. Ceci montre en particulier la nécessité d'utiliser dans les dispositifs d'enregistrement des circuits sélectifs pour fréquence musicale. Faute de cette précaution les enregistrements seraient impossibles par suite du brouillage causé par des postes puissants même assez éloignés.

Les résultats obtenus sont représentés par la figure 2 dont nous donnons comme précédemment une représentation schématique en en exagérant les particularités.

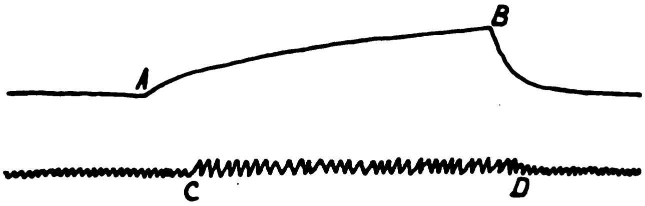

FIG. 2.

La fermeture du manipulateur provoquant le signal a lieu à l'instant A. On voit que les oscillations n'ont atteint la fréquence correspondant à l'onde de travail qu'à l'instant C donc légèrement en retard sur la manœuvre du manipulateur, de même celui-ci est ouvert à l'instant B et ce n'est qu'à l'instant D que la fréquence des oscillations musicales enregistrées cesse de correspondre à l'onde de travail. L'intervalle de temps AC mesuré sur le cliché est égal à 0,005 seconde.

Or, précisément les retards élevés constatés plus haut étaient de l'ordre de 0,006 seconde. Le retard dû à la détection serait de l'ordre de 0,001 seconde, les 0,005 seconde supplémentaires étant dû au retard de l'émission sur la manœuvre du manipulateur. Pour vérifier qu'il en était bien ainsi, nous avons rétabli l'amplificateur M_1 et repris les mesures de retard en employant encore pour l'émission du signal la mise en court-circuit d'une partie de l'inductance du poste émetteur.

Mais le condensateur shuntant la résistance de liaison lampe détectrice-lampe à courant continu n'avait pas été rétabli.

Dans ces conditions les oscillations de fréquence musicale sont très visibles et c'est leur apparition dans le trait du signal enregistré que nous prenons comme début du signal. Le cliché 3 (fig. 3 et 4) représente les résultats obtenus.

On constate bien que l'apparition des oscillations dans le trait caractéristique du signal enregistré est en retard de 0,005 seconde sur le moment où le spot correspond à l'émission du signal a commencé à dévier, mais que le spot correspondant au signal enregistré dévie à 0,001 seconde près au moment où les oscillations de fréquence musicale commencent à paraître. Le retard dans ce cas serait de l'ordre du millième de seconde. Il est un peu plus faible que dans les premières expériences, ce qui peut correspondre au temps de charge du condensateur shuntant la résistance de liaison qui avait été supprimée dans les dernières expériences.

On peut donc bien affirmer que le retard est compris entre 0,001 et 0,002, plus vraisemblablement de l'ordre de 0,002 seconde. Il importe de remarquer qu'une précision plus grande n'est pas possible.

La détection par fréquence musicale ne peut commencer que pour la première alternance rendant positive la grille de la lampe détectrice. Il y a donc sur le moment où peut se produire cette détection une indécision de l'ordre de la durée d'une alternance. Si pour des raisons de commodité, on est amené à régler la note de battement des oscillations à une fréquence un peu basse (500 périodes par seconde) l'indécision est de l'ordre du millième de seconde.

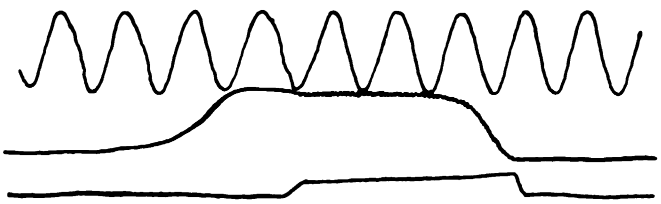

FIG. 3.

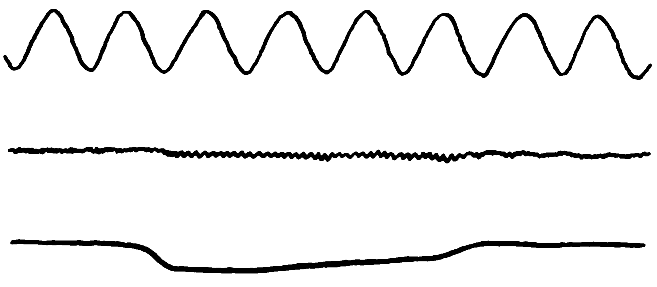

FIG. 4.

Le cliché 3 manifeste certaines particularités curieuses. Nous retrouvons bien sur ce cliché la période de décharge du condensateur shunté qui prolonge le signal d'environ 0,015 seconde, mais en outre, nous constatons avant cette période un autre retard à la cessation du signal du même ordre de grandeur et dans laquelle les oscillations de fréquence musicale se manifestent encore. Nous attribuons cette persistance des oscillations de fréquence musicale à la présence de l'amplificateur M_1. Comme nous l'avons dit, cet appareil renferme des circuits d'accord pour la fréquence musicale. Un amplificateur dans lequel les liaisons entre lampes sont assurées par circuit accordé, a toujours tendance à l'accrochage, c'est-à-dire que les réactions de l'appareil tendent à annuler la résistance ohmique des circuits oscillants. On comprend que dans un semblable circuit à résistance très faible, les oscillations une fois amorcées mettent un certain temps à s'arrêter alors même que la cause qui leur a donné naissance est supprimée. Les radiotélégraphistes traduisent ce fait en disant que les appareils à circuit syntonisés trop peu amortis, ont une tendance à faire coller les signaux. Nous voyons là encore une raison de plus pour ne pas prendre pour instant du signal le milieu de l'enregistrement.

Signaux faibles. — Toutes les expériences dont nous venons de parler ont été faites avec des intensités de signaux de valeur moyenne. Le couplage entre l'émetteur auxiliaire et l'aérien de réception était réglé de façon que de l'avis des opérateurs ordinaires, l'écoute à la sortie de l'amplificateur haute fréquence parût un peu moins intense que celle du poste de Bordeaux LY qui est enregistré journellement au B. I. H.

D'autres expériences ont été faites en diminuant beaucoup le couplage de façon à avoir des signaux très faibles. L'enregistrement était fait en laissant les appareils amplificateurs dans le même état que pour l'enregistrement des signaux forts.

Ceci n'est pas du reste le cas de la pratique. L'amplificateur sélectif M_1 est un appareil anti-parasite qui joue d'autant mieux son rôle qu'on réduit davantage son amplification en diminuant le chauffage des lampes.

Dans la pratique, lorsqu'il s'agit de postes forts et rapprochés, l'amplificateur de l'appareil M_1 est diminuée au maximum. Au contraire, lorsqu'il s'agit de postes éloignés (Annapolis, Saïgon) on donne à l'appareil M_1 la plus grande amplification compatible avec son fonctionnement anti-parasite, de sorte qu'en réalité, les signaux, qu'ils proviennent de postes rapprochés ou éloignés, arrivent à peu près avec la même intensité à l'appareil. Les circonstances dans lesquelles nous nous placions étaient donc susceptibles de mettre en évidence des retards qui n'interviendraient pas dans les conditions habituelles d'emploi des appareils.

Toutes les expériences du groupe 3 ont été refaites avec des signaux faibles.

Nous donnons un cliché n° 4 (fig. 5 et 6) représentant des expériences faites avec des signaux faibles.

Ici les oscillations de fréquence musicale ne sont plus visibles, on ne peut que mesurer le temps qui s'est écoulé entre la fermeture du manipulateur et le moment où le spot de l'oscillographe commence à dévier, ce temps est de l'ordre de 0,006 et nous savons que le temps nécessaire pour que les oscillations atteignent la fréquence correspondant à l'onde de travail est de 0,005. Le retard n'a donc pas été augmenté par la faiblesse des signaux.

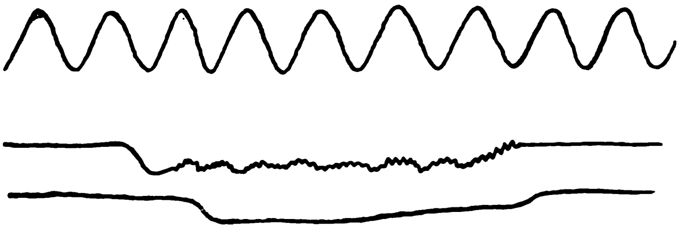

FIG. 5.

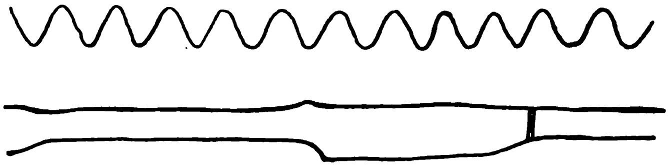

FIG. 6.

Enregistrement sur papier enfumé. — Les retards que nous avons évalués jusqu'ici sont ceux inhérents au dispositif amplificateur. Mais il est légitime de se demander si les appareils enregistreurs généralement employés n'amènent pas des retards supplémentaires par suite de leur inertie. Pendant toutes les expériences dont nous venons de parler les enroulements des oscillographes **Abraham** étaient en série avec l'équipage correspondant de l'oscillographe **Blondel** et en même temps que des relevés photographiques étaient effectués avec ce dernier appareil, les enregistrements hatituels étoaient exécutés sur le papier recouvert de noir de fumée.

La seule conclusion que l'on puisse tirer à première vue du dépouillement de ces enregistrements est la suivante :

« Il n'existe aucune différence de retard entre l'enregistrement des signaux faibles et des signaux forts. »

Cette conclusion par elle-même est fort importante puisqu'elle répond pour les appareils utilisés au B. I. H. à la question posée par M. Lambert : *Le retard dans l'enregistrement* n'augmente-t-il pas quand le poste émetteur est plus éloigné du poste récepteur?

L'évaluation du retard absolu était plus difficile à faire sur les enregistrements. Le tracé du style sur le papier enfumé ne présente pas les particularités qui sur les clichés, nous ont permis de fixer le moment exact du début du signal.

Mais, grâce aux clichés photographiques, nous connaissions le temps écoulé entre la manœuvre devant déclancher le signal et le moment où le poste émetteur oscillait avec la fréquence pour laquelle les appareils récepteurs étaient réglés.

Il était donc permis d'apporter de ce chef une correction aux retards mesurés sur la bande de papier enfumé. On a ainsi constaté que les oscillographes Abraham généralement utilisés, ajoutaient un retard de 0,002 seconde, à celui produit dans les appareils récepteurs.

Conclusion. — On peut donc dire que dans les appareils enregistreurs utilisés au B. I. H. pendant l'opération des longitudes, le retard entre l'arrivée du signal et son enregistrement était de 0,004 seconde, et qu'il était indépendant de l'intensité des signaux reçus.

Toutefois nous croyons devoir ajouter quelques remarques.

Nos expériences ont nettement prouvé que les émetteurs n'obéissent pas immédiatement à la manœuvre destinée à provoquer l'émission du signal.

Nous avons vu, par exemple, qu'en mettant en court-circuit une partie de l'inductance du circuit oscillant de l'émetteur, il faut un temps de l'ordre de 0,005 seconde avant que la fréquence n'atteigne sa valeur normale. Pareille chose doit se produire dans la manipulation des postes à arc. Nous avons de fortes raisons de croire que des faits de même genre se produisent aussi dans la manipulation des alternateurs.

Il en résulte que si dans un dispositif récepteur comme celui du B. I.H., muni de dispositifs sélectifs donnant une résonance très aiguë, le signal est enregistré seulement lorsque le signal émanant du poste émetteur se trouve exactement sur la longueur d'onde de travail, il peut arriver que, pour un autre dispositif de réception moins syntonisé, l'enregistrement du signal ait lieu un peu avant, surtout s'il s'agit d'un poste rapproché. Cette cause d'erreur n'est peut-être pas très grave pour une opération de détermination de longitude, mais il semble en résulter que des précautions spéciales devront être prises si, dans un travail de ce genre on avait pour but de déterminer aussi exactement que possible la vitesse de propagation des ondes.

Evaluations de l'heure d'un signal par la méthode des coïncidences. — Un certain nombre d'observatoires non munis de dispositifs enregistreurs ont utilisé pour évaluer l'heure des signaux radiotélégraphiques, la méthode des coïncidences en écoutant simultanément les signaux et les battements de la pendule. Il importe de remarquer que dans ce cas le retard provenant de la détection de la fréquence musicale et de l'inertie des appareils enregistreurs ne se produit plus.

Mais, d'autre part, il ne faut pas oublier que la méthode des coïncidences ne comporte pas la même précision que l'enregistrement des signaux. En particulier les irrégularités de la durée des secondes, irrégularités provoquées par les rouages des pendules et qui peuvent atteindre plusieurs millièmes de seconde rendent souvent difficile l'appréciation exacte de la coïncidence.

Cette appréciation est du reste de l'avis des expérimentateurs beaucoup moins facile avec les

ondes entretenues reçues par la méthode des battements, qu'avec les ondes amorties employées jadis.

Nous estimons donc que la méthode des coïncidences ne doit être considérée que comme un pis aller et doit être partout où ce sera possible, remplacée par la méthode d'enregistrement.

Juin 1928.

RADIO DIRECTION-FINDING BY TRANSMISSION AND RECEPTION

(With Particular Reference to its Application to Marine Navigation)

by R. L. SMITH-ROSE.

(The National Physical Laboratory, Teddington, England.)

SUMMARY. — *This paper presents a critical résumé of the performance of apparatus employed for radio direction determination either by transmission or by reception. After an historical summary of results obtained in various parts of the world, a brief description is given of the fundamental principles underlying radio direction-finding. In this section attention is drawn to the application of the principle of reversibility to this art, by the aid of which the behaviour of directive radio transmitters can be largely predicted from the more numerous results and greater experience already obtained with directional receivers.*

The next two sections of the paper give a review of the results obtained in Great Britain during the course of extensive investigations into this subject during the past seven years. Observations obtained from thirteen direction-finding receiving stations, specially erected for the purpose, have been carefully analysed and the performance of the apparatus studied under a variety of conditions, including operation in daylight and darkness, and both oversea and overland. In addition, some two years have been spent in studying the performance of a rotating-loop beacon transmitter, by means of which accurate radio bearing can be obtained with any type of receiving apparatus.

The later portions of the paper deal with the applications of direction-finding to marine navigation, and of the possible effect of coastal and night errors in connection therewith. The production of night errors on closed loop receivers by the horizontal component of the electric force in downcoming waves is explained, and a demonstration is given of the manner in which the Adcock aerial system gives freedom from such errors. The paper concludes with a discussion of the relative advantages of direction-finding by transmission and reception for navigation purposes. A bibliography of the subject is appended.

1. Historical.

The application of the radio direction-finder both as a navigational instrument and as a useful scientific tool in the study of the propagation of electromagnetic waves has been developing rapidly during the past few years. As a result, a number of text-books expressly devoted to the subject of directional wireless have appeared, and the reader must be referred to these (1) (*) and other published works for an account of the fundamental principles of the art of direction-finding and its historical development. The object of this paper is to present a critical résumé of the results of investigations been carried out over a period of several years into the performance of direction-finding systems, and the historical background provided in this section will be confined to this aspect of the subject.

A) *The Direction-Finding Receiver.* — The modern radio direction-finder undoubtedly owes its success very largely to the introduction of valve amplifiers, enabling a moderately large reception range to be obtained, and its practical development therefore dates from about 1915. Previous to this, such systems of direction-finding as were in existence were confined to short-distance working and the comparatively crude instruments then in use made accurate systematic observations difficult to obtain. As early as 1908, however, Pickard (2) observed that lar-

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(*) See bibliography, p. 82.

ge errors might be obtained in the reading of coil direction-finders due to buildings, trees, and other obstacles in the neighborhood. In the diagrammatic representation of his results, the errors are shown, to be approaching 90 deg. It was found also by Fessenden (3) in the years 1901-07, that errors in apparent direction of as much as 20 deg. to 45 deg. might be obtained in the indication of these instruments when receiving over a range of 100 miles. These errors were attributed to a refraction effect resulting from the difference in conductivity of land and sea-water, or even to a varying local conductivity of the ground and of vegetation. In making continuous observations day and night for a week, Fessenden was apparently the first to observe that the errors were greatest during the night, a fact which he attributed to a refraction effect of large clouds of ionized air in the path of the waves.

A method of obtaining an absolute zero of signal-strength on a small frame-coil direction-finder was described by A. H. Taylor (4), in which the « antenna effect » of the coil is compensated for by a small e. m. f. from an auxiliary frame at right angles to the first. Using this system at Washington, it was found that while readings taken in the daytime were fairly accurate those taken near sunset and at night were very erratic. While it appeared that the variations observed on continuous waves of wavelength 13,600 meters were greater than on shorter waves, they were quite serious on damped waves of 1,500 meters wavelength. These variable results were briefly ascribed to reflection and refraction effects occuring during the propagation of the electromagnetic waves over the earth's surface.

The liability of the metalwork of a ship to produce a quadrantal error in the readings of a direction-finder mounted thereon was mentioned by Blondel (5) in 1919, while the corresponding effects on an aeroplane were later described by Robinson (6). The complete theory of the effect of the metal hull of a ship on a direction-finder was first given by Mesny (7) in 1920. Calculations from this theory, confirmed by experimental results, showed that the quadrantal error obtained may be as great as 12 deg. This error was shown to be independent of wavelength and to decrease with the height of the frame coil above the deck. Attention was also drawn in the above paper to the approximately analogous case of a direction-finder erected upon a hill or an island, and the resulting quadrantal error which may be obtained in such a case is illustrated by a curve having a maximum value of 15 deg.

The phenomenon of the refraction of electromagnetic waves in passing over a surface of suddenly changing conductivity was discussed by T. L. Eckersley (8) in 1920. Experimental observations made in Cyprus and Egypt on wavelengths between 800 and 1,100 meters showed that wireless waves in crossing a coastal boundary between sea and land might suffer a deviation of as much as 4 deg. This deviation falls to zero for normal incidence of the waves on the coast line, and it was also shown to be negligible for wavelengths exceeding 2,000 meters. In the paper there is quoted an interesting case of a bad day minimum being produced by the reception of two waves from a transmitter, the two waves arriving by different paths and with a phase difference which resulted in a rotating field.

Somewhat similar refraction effects on wireless waves passing from dry to wet ground and across a river were mentioned by Kiebitz (9) in connection with experiments on a directional transmitter. The deviations of the waves amounted to 8 deg. or 9 deg. for a wavelength of 550 meters.

Some results showing the errors to which a radio direction-finder may be subject due to local conditions were given by Hollingworth and Hoyle (10). Masses of metalwork, tuned circuits, and overhead wires were found to produce a appreciable errors in the readings.

In a most valuable paper published in 1920, Round (11) gave an account, chiefly from his personal experience, of the development and application of the direction-finder during the war. The manner in which the instrument was perfected as a useful tool for both military and naval purposes was described together with the various types of errors encountered, both by day and by night. Reference was made to the work of Adcock, Eckersley, and Wright in connection with these errors, and a brief indication was given of the means by which they might be eliminated for practical direction-finding purposes.

A large amount of experimental work on the intensity and directional properties of the electro-magnetic field radiated from an aeroplane transmitter was described by Baldus, Buchwald, and Hase in 1920, (12) while a mathematical treatment of this case was given by Burstyn. (13) The errors in the apparent bearings of an aeroplane at a ground direction-finding station were discussed in detail in their relation to the plane of polarization of the emitted waves. The experiments of Baldus and Buchwald, in particular, showed that a closed-coil direction-finder on the ground could give errors of as much as 60 deg. in the bearings of aircraft. This fact is interesting in connection with the patent filed by Adcock (14) in 1919, in which was described a means of eliminating the error of observation of the orientation of aeroplanes.

Some further observations on the variable night errors were published in 1920 by Kinsley and Soby (15). Variations in the apparent bearings ranging up to 50 deg. were recorded on wavelengths between 960 and 17,300 meters, and for ranges of transmission from 40 up to 7,500 miles

Towards the end of 1920, the Department of Scientific and Industrial Research in England, acting on the advice of its Radio Research Board, began the erection of a number of directional radio receiving sets in various parts of the British Isles, attached either to Universities or to Government experimental establishments. The object of these installations was to make regular observations of the apparent radio bearings of various transmitting stations in order to obtain data on the nature, magnitude, and other characteristics of the variations of bearings which were previously known to take place. The general organization and conduct of this investigation was carried out by the author from The National Physical Laboratory, Teddington, as headquarters. Up to the time of the termination of the general investigation in September, 1926, about a quarter of a million observations had been accepted for correlation, these observations covering the range of wavelengths of 300 to 20,000 meters. A detailed record of the work, with discussion of the conclusions drawn therefrom, has formed the subject of a number of official reports published by H. M. Stationery Office, England (16). In addition to these publications, descriptions of various investigations subsidiary to the main line of research have been published elsewhere. For example, in order to obtain accurate bearings in continuous wave working it was found necessary to prevent any mutual induction between the local oscillator and the receiving frames of a Robinson direction-finder by suitably screening the local oscillator. (17) Such screened oscillators have now been in use for several years in connection with various direction-finding work, and nowadays they find considerable application in radio measurements work.

These experiments were later extended to that of screening assemblies of amplifying and receiving apparatus to prevent the undesired direct induction of signals. Data were obtained by Barfield (18) for the screening of a complete hut containing the receiving apparatus as, for example, in the Bellini-Tosi direction-finding system. In the course of the same investigation Barfield demonstrated the properties of open wire screens, and these were later applied to the reduction of the error known as « antenna-effect » in radio direction-finding.

Various experiments were carried out in the early stages of the main investigation to ascertain the effect of local conditions such as metalwork, overhead wires, trees, etc., on the readings of direction-finders. (19, 20) These experiments showed that some quite large errors, ranging up to 22 deg., can be produced by the proximity of such obstacles and emphasize the importance of exercising care in selecting a suitable site for a direction-finding installation. The difficulty in finding any approach to an ideal site was illustrated by the results obtained from the stations selected. In very few cases was the error due to local conditions less than 2 deg. It is fortunate, however, that such a type of error remains constant in value for any particular direction, so that it can be treated as of the nature of a permanent deviation, which can be ascertained periodically from a calibration of the station. In the case of the Aberdeen station, the cause of permanent errors ranging up to 15 deg. was traced to a long iron plate beneath the ground and supporting a sewer duct, over which the direction-finding installation was inadvertently erected. (20)

During the course of the main investigation each of the three practical types of direction-finder, known as the Bellini-Tosi, Robinson, and single-coil systems, respectively, has been used in some portion of the investigation : and it was naturally desirable to verify whether comparable results could be obtained with any of these systems. A simple consideration of the theory shows that there is no essential difference in the basic principle of any of the systems, for in each case the reading of the direction is made as the result of some portion of the apparatus rotating minimum, or in the ideal case, zero e. m. f. induced about a vertical axis being set in the position in which there is a minimum, or in the ideal case, zero e. m. f. induced by the incoming waves. This theory was discussed in a previous publication (21) which also contained a description of the results of experiments showing that each system was equally subject to variable night errors.

B) *The Direction-Finding Transmitter.* — As an alternative to the use of a special radio receiving instrument for the determination of bearings the directional property can be transferred to the transmitting station, so that its direction can be determined at a distant receiving station by the aid of some characteristic of the emitted radiation.

Both of the types of directional transmitting systems which are in use today may be said to date from the time of Hertz, since in his experimental researches Hertz used reflectors to concentrate the radiation from a straight rod aerial and also loops whose transmission or reception properties depend upon the orientation of the loop. Of recent years the properties of reflecting systems used in conjunction with linear aerials have been studied by Marconi (22), Franklin (23), and others (24), and with the application of the beam system to long distance communication considerable development has been taking place in many countries. The beam system has also been adapted as a rotating beacon transmitter (25), but practical limitations necessitate its operation on the very low wavelengths of 6 to 10 meters. Experimental beacons of this type habe veen installed at Inchkeith (22, 23) and South Foreland (25), but it is believed that its use among ships has not been very widespread.

The predecessor of the closed loop antenna, whether for reception or transmission, is to be found in either the inverted *L* aerial or in a pair of spaced vertical aerials. The former has developed into the Beverage aerial which is now used as one method of obtaining directional selectivity at the receiving end. A system of inverted *L* aerials giving directional transmission has been experimented with by Scheller, Buchwald (26), and Keibitz (27). For navigation purposes it is also probable that the Telefunken compass (28) arrangement falls under this heading. This system made use of a series of directional aerials radiating from a central mast, these aerials being excited in turn by a rotary switch operating at a speed of one revolution per minute. A non-directional aerial was also provided for the purpose of transmitting a timing signal applicable to the directive system. By noting the interval between this time signal and the reception of the signal from the directional system, the bearing of the transmitter could be estimated from a distant receiver.

The combination of the pair of spaced aerials developed first into the Bellini-Tosi system of direction-finding and later into the rotating frame coil. The transmitting equivalent of the Bellini-Tosi direction-finder is to be found in the Radiophare, several of which were in operation on the French coast prior to 1914. In the same manner the single-frame coil can be adapted to transmission since its polar radiation characteristic is the well-known figure-of-eight diagram, and thus the intensity of the radiation varies according to a cosine law with the angle between the plane of the loop and the direction of transmission. One of the great advantages of a loop transmitter is that it can be operated on the wavelengths usually employed in ship and aircraft wireless communication. Various methods of applying the rotating loop transmitter for navigation purposes were described by Erskine-Murray and Robinson in 1922 (29), while more recently Gill and Hecht (30) have recounted the development of the rotating beacon by the British Air Ministry and supplied some typical results obtained in the application of this system to the navigation of aircraft.

The use of two directional transmitting aerials sending complementary Morse signals (such as A and N) upon the same wavelength for the purpose of providing an equi-signal zone along a fixed course appears to have originated with Scheller in Germany, and to have been investigated by Buchwald (26) and Kiebitz (27) in 1920. With the substitution of closed loops for the open inverted *L* aerials previously employed, Engel and Dunmore (31) published in 1924 an account of experiments designed to illustrate the utility of this system for the navigation of both ships and aircraft. This method is not strictly one of direction-finding since the observer or navigator is not generally able to determine his bearings or position by this means, but only to locate himself along a fixed course as given by the beacon transmitter. For this reason the system is more directly applicable to the navigation of aircraft flying along fixed routes than to the navigation ships; and it is from this point of view that considerable development of the method has recently been carried out in the United States of America. This work has been described by Dellinger and Pratt (32), who have applied a modified form of the radiogoniometer to enable the course or equi-signal zone given by the transmitter to be oriented in any required direction. The limitation of range of the system for accurate direction indications is illustrated by the results of some experiments reported by Pratt (33), in a separate paper. In common with all closed loop transmitters and receivers for direction-finding this system becomes liable to serious errors at ranges exceeding about 100 miles, even when the receiver is some 2,000 feet above the ground.

For further detailed information on the application of radio communication to aircraft navigation, the reader may be referred to the Bibliography recently published by Jolliffe and Zandonini (34).

2. Brief Description of Methods of Direction Determination by Radio Transmission or Reception.

A) *The Radio Direction-Finder.* — The radio direction-finder is now well known as an instrument which can be used to determine the direction of arrival of wireless waves, and it will suffice to give the briefest outline here of the principles underlying this instrument. The several commercial types of direction-finder now in use employ the same fundamental principle of the reception of vertically polarized (*) wireless waves by a frame coil. In figure 1 (*a*), for example, let C represent a plane vertical loop rotating about a vertical axis in the field of an arriving wave whose component electric and magnetic forces are as shown. From the plan view in figure 1 (*b*) it is evident that the e. m. f induced in the loop by the arriving waves will be proportional to the cosine of the angle α between the direction of the magnetic field and the axis of the coil. The accuracy with which any definite position of the coil may be located depends upon the rate of change of e. m. f. with orientation, i. e., the accuracy is proportional to sin α. Thus the determination of the direction of arrival of the waves is most accurate when the signal

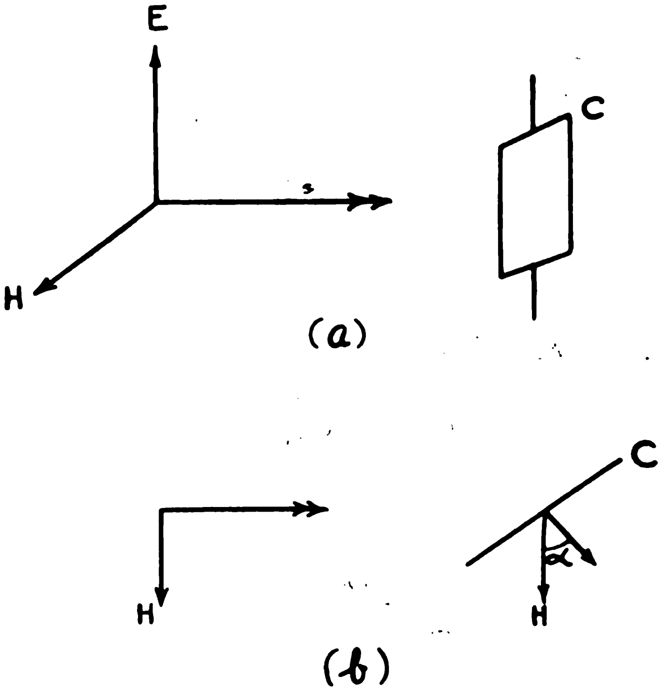

FIG. 1.

(*) The term « vertically polarized » is used here to indicate that the electric force of the wave lies in the vertical plane of propagation of the wave.

e. m. f. induced by the waves is zero. This point is also illustrated by figure 2, which shows the theoretical polar reception diagram for a rotating loop. The strength of the signal e. m. f. induced in the loop by a wave arriving from any direction is proportional to the intercept of the vector OA made by the « figure of-eight ».

The most important feature which requires attention in the design of a practical direction-finder is the avoidance of spurious e. m. f's introduced into the system from one or both of the phenomena commonly known as « antenna-effect » and « direct pick-up. » The term « antenna-effect » is applied to the property possessed by a frame coil receiver of acting as an untuned vertical aerial as well as a coil for reception purposes. As a result of this, the receiving system may have induced in it an e. m. f. whose phase and magnitude are independent of the orientation of the coil. The signal heard in the telephones will be the sum of that produced by the rotating coil as such and that due to the equivalent aerial effect of the whole receiver. As the coil is rotated it is found that the signal zeros become blurred into broad minima only, and moreover, they may be displaced from their correct positions. The existence of this antenna effect in the system therefore makes the observed directions incorrect, and also makes the determination of these directions more difficult.

Somewhat similar results may be produced by the second of the two causes mentioned above, viz. « direct pick-up. » This last term implies that portions of the receiving system, such as the tuning circuits and the amplifier, are having e. m. f's induced in them directly by the incoming waves. These e. m. f's will obviously be independant of the orientation of the main receiving frame, and they will be effective in adding to or subtracting from the signal strength finally heard in the telephones. It must be appreciated that while these stray e. m. f's may be small compared with the main e. m. f. picked up by the rotating frame-coil in its maximum position, they become of very great importance when the coil is turned into its minimum position.

The methods adopted for overcoming the effects of these spurious e. m. f's are based on the use of somewhat elaborate screening arrangements, with or without the addition of a compensating condenser for the antenna effect. The application of these methods to the practical arrangement of single-coil direction-finders has been described by Kolster (35), Dunmore (36), Long (1*g*), Mesny (*f*) and the author (37); and the reader must be referred to these descriptions for further details of such apparatus.

With the object of enabling the incoming signal to be clearly audible throughout the whole process of taking a bearing, a crossed-coil arrangement was described Robinson (38) in 1920. This system was, at one term, particularly favored for use of aircraft, but with some modifications described by Bainbridge-Bell (39), it now finds widespread application to marine navigation.

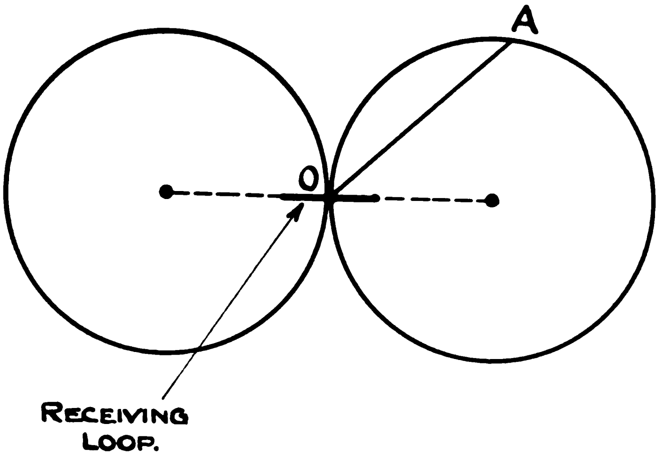

FIG. 2.

Before the development of valve amplifiers made possible the use of rotatable multi-turn loops, Artom in 1903 and Bellini and Tosi in 1907 suggested and used large frames of a triangular shape, with the ends open at the top apex, for directional wireless communication. The arrangement developed from this and now generally known as the Bellini-Tosi system was fully described in 1908 (40). The large, fixed closed loops employed in this system are connected to a radiogoniometer, an instrument which reproduces in miniature the directive properties of the external field of the waves Recent developments of this system for use in ships have resulted in the employment of smaller multi-turn loops, which are more conveniently fixed on board. The development and use of the Bellini-Tosi system during the war was described by

Round (11) in 1920, while Horton (41), Slee (42), and Mesny (43) have dealt with some more recent developments.

B) *The Rotating Loop Transmitter.* — As an alternative to the direction-finding schemes outlined above, the directional part of the wireless system may be transferred from the receiving to the transmitting end. Thus is effected in the rotating loop beacon system, which has been developed to a high degree in Great Britain by the Royal Air Force, and which employs a vertical closed loop transmitter arranged to rotate about a vertical axis at a uniform speed of one revolution per minute. The polar radiation diagram of such a loop will be of the same figure-of-eight form as that shown in figure 2 for a loop receiver. Thus as the loop rotates the field radiated in any given direction will vary according to a cosine law, passing through successive maximum and minimum values at intervals of fifteen seconds. When the plane of the coil is perpendicular to the geographical meridian a characteristic signal is emitted by the beacon which may be termed the N point. An observer at a distant receiving station upon hearing this signal starts a chronograph. As the beacon rotates the intensity of the received signal varies and will ultimately pass through a minimum or zero value, at which instant it is known that the plane of the transmitting loop is at right angles to the great circle joining ransmitter and receiver. If the reading of the chronograph is observed at this instant of minimum signal intensity it is evident that the bearing of the transmitter from the receiver can be obtained by a simple calculation. To provide for the case in which the observer is due north or south of the beacon, when the N signal would probably be inaudible, another characteristic signal is emitted after a 90 deg. rotation to the corresponding *E* point. Bearings observed from this signal as a starting point are evidently subject to a correction of 90 deg. It is to be noted that since the radiation from the coil is symmetrical about its plane, a second minimum will be obtained after a rotation of 180 deg. from the first. With the beacon making one revolution per minute, therefore, a line bearing is obtainable in the above manner every half-minute. To fix the position of a receiving station it is necessary to obtain line bearings in this manner from two or more beacons.

Since the timing process mentioned above is but an intermediate step in taking a bearing, it is convenient to provide a stop-watch or chronograph used for the purpose, with a dial specially engraved in degrees and points of the compass as illustrated in figure 3. If the center second-hand of such a watch is started on the *N* signal from the beacon, the indication of the hand at the occurrence of the signal minimum will give the true bearing of the observer. Examples of other dials suitable for working from the *E* point, and on beacons with different times of rotation, have been described elsewhere (44*a*).

The development and initial testing of this rotating beacon system by the Royal Air Force have naturally been confined to a study of its advantages over the direction-finding receiver for the navigation of aircraft (30). During the past few years, however, the author has been privileged to investigate the performance of a rotating beacon station, especially set up for the purpose in England, and particularly to ascertain its advantages and reliability as an aid to marine navigation (44). A sketch photograph of this beacon is shown in figure 4.

C) *The Reversibility of Direction-Finding.* — From the brief description of fundamental principles given in the two previous sections it will be gathered that wireless direction-finding can be carried out by rotating a closed loop at either the transmitting or receiving end of a communication link. The directional property is given by the rotating closed loop and the other station can employ any type of wireless transmitter or receiver connected to any type of aerial system. It will probably aid the reader in understanding the performance of each system and their relative merits for any given purpose, if attention is drawn here to the reversibility of the communication system between an open aerial and a closed loop.

The reference of the reciprocal theorem to radio communication has been enunciated by Lorents, Pfrang, and Sommerfeld (45), who discussed its application to transmission between

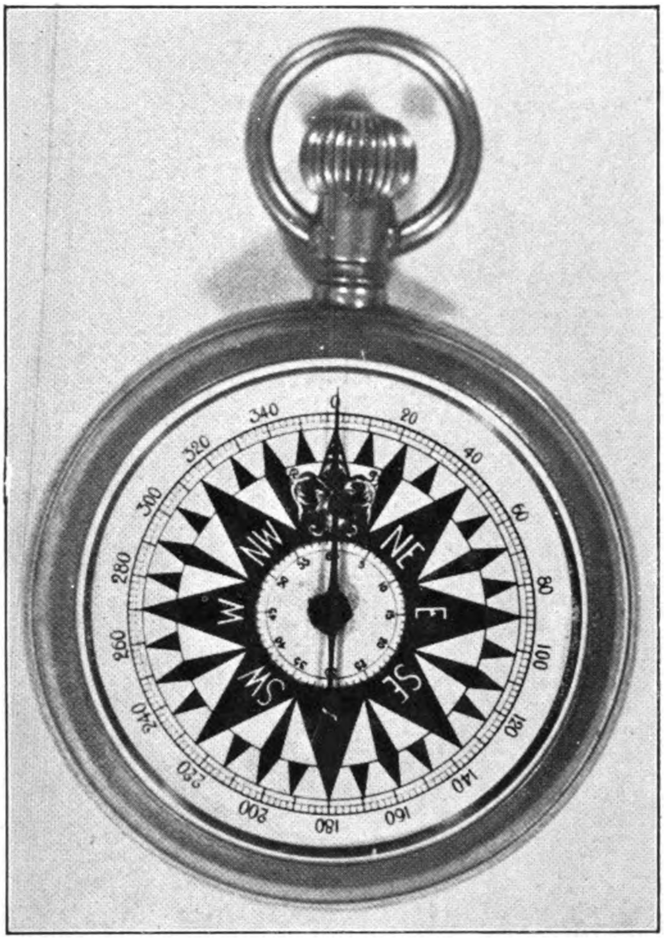

FIG. 3.

Stop Watch Fitted with Special « Compass-Card » Dial for Use in Taking Bearings from a Rotating Beacon.

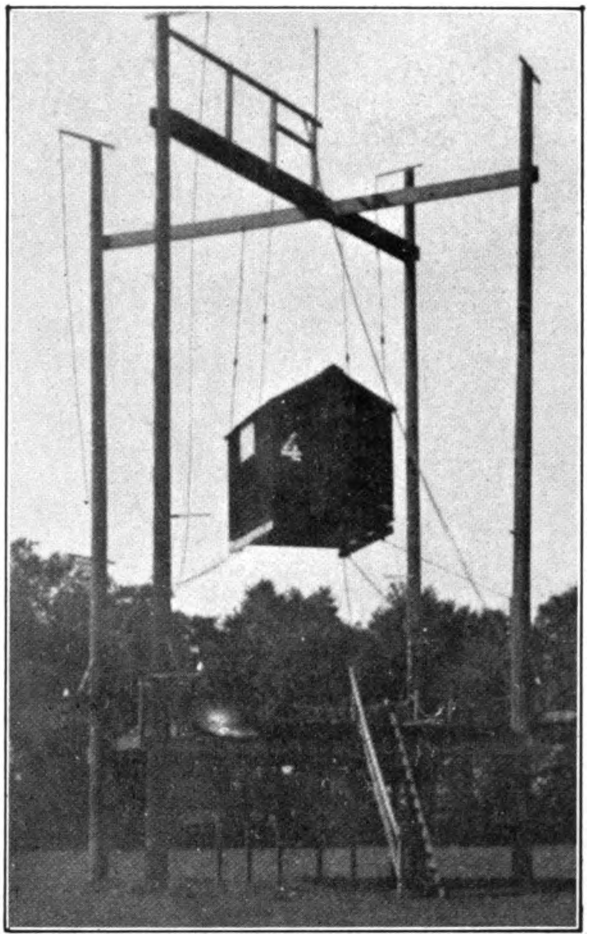

FIG. 18.

View of Hut Suspended at the Center of an Adcock Aerial System. The hut contains the radiogoniometer and receiver used in taking bearings free from night errors.

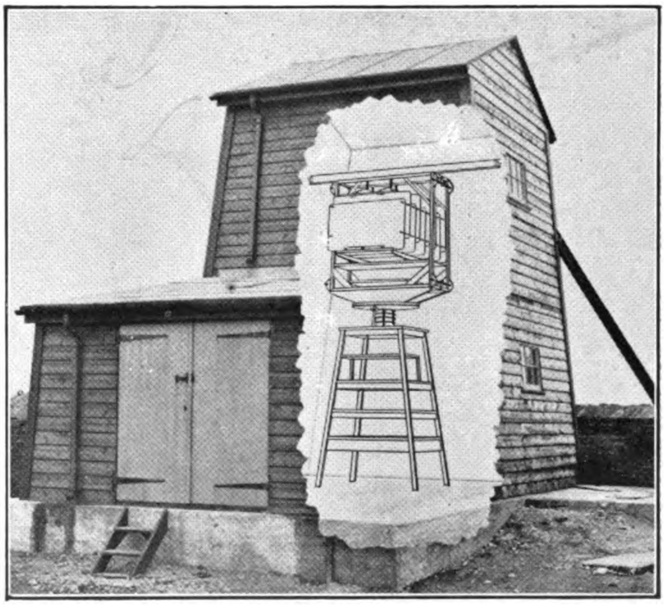

FIG. 4.

View of Rotating Beacon inside Hut at Fort Monckton, Gosport.

open aerials, closed loops, or a combination of these. The theorem may be briefly stated in the following terms : if an antenna A_1 transmits to another antenna A_2, the signal intensity in A_2 is the same as that which would be received in A_1 if A_2 transmitted with the same power and at the same frequency as was previously used by A_1. This equality of signal intensity in the two cases is independent of the electromagnetic properties of the medium and of the shapes of the antennas. This means that transmissions from a rotating loop beacon being received on an open antenna should produce errors of the same type as those experienced when the antenna is employed for transmitting to a loop direction-finder. The utility of this theorem in studying the performance of the two systems will become evident in succeeding sections of the paper, and the author has referred elsewhere to the possibilities of investigating local errors in this manner (46). On theoretical grounds, the reversibility of the Adcock direction-finding system as a means of avoiding night errors has also been established by the present author (72). In the above cases a reservation must be made as to any irreversible effects which may be produced by the influence of the earth's magnetic field upon wireless waves travelling through ionized regions of the earth's atmosphere. The possibility of such a departure form the reciprocity relation was pointed out by Appleton in 1925 (47).

3. Analysis of the Performance of Wireless Direction-Finders.

Attention has already been drawn in Section 1 to the carrying out of a large investigation in wireless direction-finding by the Radio Research Board in the British Isles during the years 1920-1926. In the course of this investigation, thirteen direction- finding stations were used in various parts of the work, which covered a range of wavelengths of from 300 to 20,000 meters. The precise distribution of these stations and the detailed results of the whole investigation will be found in a series of official reports to which reference has already been made (16). It is considered to be useful here, however, to give a very brief résumé of these results with the con-

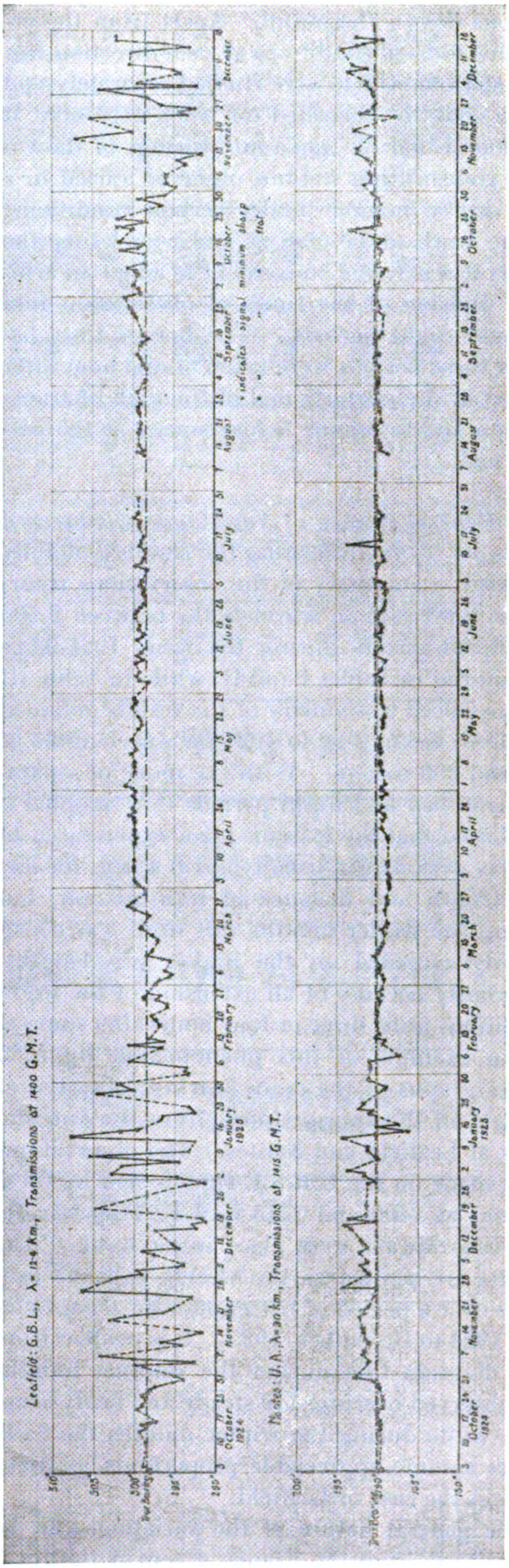

FIG. 5.
Graphs Showing the Daily Observations of Bearings Taken at Slough on the U. R. S. I. Transmissions from Leafield and Nantes. October, 1924 to December, 1925.

clusions drawn therefrom. Apart from the errors due to local conditions at each direction-finding station, which were studied separately and which could be corrected for when necessary, it was found that the apparent bearings of the various transmitting stations observed varied in a very erratic manner under certain conditions. In the work of tabulating and correlating the results it was found convenient to adopt an arbitrary division of the times of observation into day and night periods. The border lines between these periods were taken at one hour after sunrise at the westerly end of the path of transmission and one hour before sunset at the easterly end.

A) *General Nature of Variations in Observed Bearings.* — As illustrating the results generally obtained, a summary of the observations recorded at Newcastle on wavelengths between 2,500 and 6,000 meters during the years 1921-23 is reproduced in Tables I and II, while in Table III is reproduced a summary of the results obtained at Orford from 1922 to 1924 on wavelengths of 450 and 600 meters. With the mode of separation into day and night periods thus adopted it was found that the extreme error experienced in the day periods was usually about 4 deg. for any wavelength and distance of transmission, but during the winter months this limit was considerably exceeded on the higher wavelengths, apparently because of an extension of the night conditions until three or four hours after sunrise. As an example of this phenomenon figure 5 shows graphs of the daily bearings observed at Slough on the transmissions from the two stations at Leafield and Nantes. The observations were made on the U.R.S.I. signals sent by these stations at 1400 and 1415 G.M.T., respectively, and thus always took place in daylight. The results are plotted as the weekly extreme bearings over a period of fifteen months from October, 1924 to December, 1925. It is evident from this diagram that during the summer months the observed bearings are steady and fairly accurate, while during the winter months the daily errors assume appreciable proportions, particularly in the case of Leafield.

The general nature of the variations can be understood from the graphs given in figures 6 and 7, which show the apparent bearings of some fixed transmitting stations as observed every few minutes over periods of 24 hours at one observing station. It is to be noticed that the day bearings are much steadier in the summer than in the winter months, but that in either case the approach of sunset is accompanied by an increase in the magnitude and frequency of the variable errors which continues throughout the night until sunrise. During the bulk of the investigations carried out on wavelengths between 450 and 12,000 meters these variable errors in bearing ranged up to, but very rarely exceeded, 90 deg. as illustrated in the above tables.

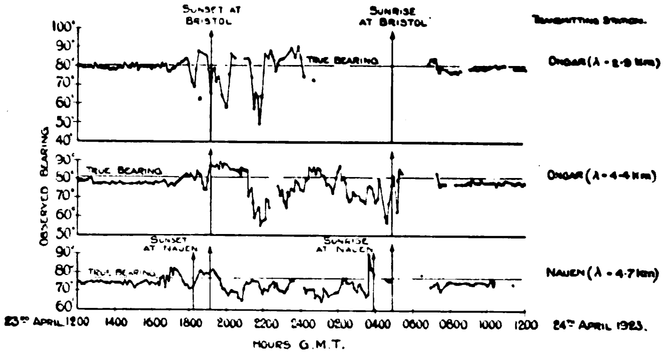

FIG. 6.

Graphs of Observed Bearings of Ongar (undamped waves, λ = 2.9 and 4.4 km) and Nauen (undamped waves, λ = 4.7 km) taken at Bristol over a 24-hour period.

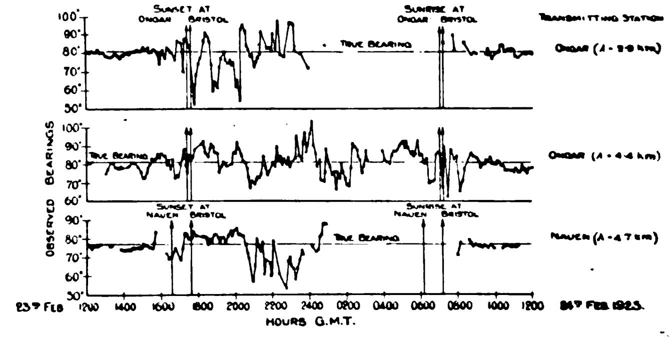

FIG. 7.

Graphs of Observed Bearings of Ongar (undamped waves, λ = 2.9 and 4.4 km) and Nauen (undamped waves, λ = 4.7 km) taken at Bristol over a 24-hour period.

In some of the later work the observations have been extended into the broadcasting band of wavelengths. A summary of the results obtained is given in Table IV, and this shows that in the case of the observations at Slough taken on the transmissions from Bournemouth, the

TABLE I.

Summary of Observations Taken at Newcatsle from February 28, 1921 to March 4, 1922.

(1)	(2)	(3)	(4)	(5)	(6)				(7)			
					Day Observations.				Night Observations.			
TRANSMITTING STATION.	Type and wavelength.	Time of transmission.	Distance.	True bearing.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.
	(km.)		(miles)	(degs.)		(degs.)	(degs.)	(degs.)		(degs.)	(degs.)	(degs.)
Aberdeen	C. W. 3.3	I	154	352.0	100	10.5	— 0.2	— 6.8	37	17.0	+ 0.1	— 11.1
Aranjuez	S. 3.5	I	1,034	184.6	65	1.7	+ 2.0	— 1.1	102	5.6	+ 1.6	± 2.8
Budapest	S. 3.0	I	1,026	111.6	45	3.5	— 1.3	— 1.8	527	29.5	— 1.1	+ 18.5
Chelmsford	C. W. 3.8	I	240	158.1	126	5.0	— 0.8	+ 2.7	256	4.0	— 0.7	+ 2.6
Cleethorpes	S. 3.0	17.00	118	147 2	—	—	—	—	87	4.2	— 0.9	+ 2.2
Cleethorpes	C. W. 4.6	I	118	147.2	72	9.3	— 0.8	— 5 2•	134	12.0	— 1.5	— 7.2
Clifden	S. 5.8	I	355	256.2	64	2.2	— 1.4	+ 2.8	4	6.0	— 3.4	+ 3.7
Clifden	C. W. 5.8	I	355	256.2	95	7.5	— 0.3	+ 6.1	182	33.0	— 0.1	— 18.1
Coltano	S. 4.2	I	948	140.6	141	3.1	— 1.9	+ 1.7	60	7.6	— 0 7	+ 5.7
Horsea	C. W. 6.0	12.00 20.00	287	175.5	204	6 5	— 0 9	+ 3.4	392	14.5	— 0.5	+ 8.0
Karlsborg	S. 4.5 2.5	12.15 20.00	650	62.4	33	6.7	— 1.4	+ 3.5	441	37.0	+ 1.7	+ 25.9
Karlsborg	S. 4.2	I	650	62.4	207	10.2	— 1.2	— 6.4	128	23 0	+ 0.7	— 12.1
Karlsborg	C. W. 4.5	I	650	62.4	27	2.3	— 0.6	— 1.3	9	4.0	— 2.3	+ 2.4
Moscow	S. 4.8	I	1,521	71.8	18	2.4	— 0.4	— 1.3	1838	34 0	+ 0.8	+ 23 4
Nantes	S. 2.5	08.00 21.00	538	180.4	2	0.3	0.0	— 0.2	8	7.6	+ 0.2	— 4.4
Nantes	S. 4.2	08.15 21.30	538	180 4	6	1.3	— 2.9	+ 0.9	5	2.0	+ 0.4	+ 1.2
Nauen	S. 3.9 3.2	11.50	612	99.2	269	3.4	— 2.5	— 2.0	—	—	—	—
Nauen	C. W. 4.7	I	612	99 2	50	13.5	— 3.1	+ 6.9	27	13.5	— 2.4	— 7 3
Nicolaieff	S. 4.0	I	1,546	96.3	160	5.8	— 0.7	+ 4.4	106	12.8	+ 1.0	+ 7.2
Paris	S. 2.6	08.15	454	156.9	202	3.0	— 2.2	— 1.7	—	—	—	—
Paris	S. 2.6	09.20 10.40	454	156.9	1138	4.3	— 2.2	— 2.9	—	—	—	—
Paris	S. 2.6	11.30	454	156.9	605	3.1	— 2.3	— 1.7	—	—	—	—
Paris	S. 2.6	19 20 21 10	454	156.9	—	—	—	—	448	8.5	— 2.1	+ 4.7
Paris	S. 3 2	11.00 12.00	454	156.9	537	3 0	— 0.5	— 1.9	—	—	—	—
Poldhu	S. 2.8	09 30 21.30	374	205 6	365	5.2	+ 0 3	+ 2.8	172	32.5	— 1.0	— 20.6
Poldhu	S. 2.8	I	374	205 6	14	1 5	+ 0.3	— 0.9	17	26.2	— 4.5	— 21.1
Sofia	S. 3.2	I	1,400	116.8	7	2.8	— 2.2	± 1.4	166	11.5	+ 0.4	+ 5.8
Warsaw	S. 2.0	I	942	92.0	60	4.0	+ 0.8	+ 2.2	23	5.6	+ 0.2	+ 3.3

I = Irregular transmission.

TABLE II.

Summary of Observations Taken at Newcastle from March 6, 1922 to March 31, 1923.

(1)	(2)	(3)	(4)	(5)	(6)				(7)			
					Day Observations.				Night Observations.			
TRANSMITTING STATION.	Type and wavelength.	Time of transmission.	Distance.	True bearing.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.
	(km.)		(miles)	(degs.)		(degs.)	(degs.)	(degs.)		(degs.)	(degs.)	(degs.)
Aberdeen	C. W. 3.3	08.30-09.30 17.00	154	352.0	189	17.5	+ 0 7	— 11.4	125	33 8	+ 0.8	+ 18.0
Aberdeen	C. W. 3.3	21.00	154	352.0	—	—	—	—	111	37.2	+ 0.5	— 19.7
Air Ministry	C. W. 4.1	I	252	162 5	247	10.3	— 1.2	+ 6 9	252	30.7	— 0.8	+ 17.5
Berne.	C. W. 3.4	I	676	140 8	530	5.1	— 1 5	— 4.3	217	56.0	— 0.6	+ 34 3
Budapest.	S. 3.0	I	1,026	111.6	48	4.0	— 2.0	+ 2.4	26	7 1	0.0	+ 4.0
Chelmsford	C. W. 3.8	I	240	158 1	76	4.4	— 1.6	+ 2.9	70	2.5	— 1.9	+ 1.3
Cleethorpes	C. W. 4.3	08.00	118	147.2	118	12.0	— 1.5	— 6.2	—	—	—	—
Cleethorpes	C. W. 4.3	I	118	147.2	116	8.5	— 2.3	— 4.9	187	21.0	— 0.3	— 11.9
Clifden	S. 5.8	09 50 21.50	355	256.2	85	1.5	— 1.4	— 0.8	66	12.5	— 2.5	— 7.7
Clifden	C. W. 5.8	I	355	256.2	316	2.3	— 0.5	+ 1.4	594	26.0	— 0.4	+ 14 2
Coltano	S. 4.2	I	948	140.6	169	3 3	— 1.9	— 2.2	244	10 8	— 1.6	± 5.4
Horsea	C. W. 5.0	I	287	175.5	193	13.6	— 0.8	+ 8 8	98	15.6	— 1.3	— 9 3
Karlsborg	S. 2.5	12.15 20.00	650	62 4	171	6 6	+ 0.1	+ 3 5	485	57 5	+ 5.1	— 31.5
Karlsborg	S. 4.2	I	650	62 4	125	6.2	— 0 5	— 4.3	53	26.3	+ 0.1	+ 15 0
Karlsborg	C. W. 3.9	I	650	62.4	503	10.5	+ 2 2	— 7.1	237	55 0	+ 3.8	+ 38 8
Konigswusterhausen	C. W. 5.2	I	658	100.0	501	8 3	— 2.6	— 4.2	260	32 4	— 3.3	— 20.7
Moscow	S. 4.8	I	1,521	71.8	421	5.5	— 1.6	+ 2 8	945	39.0	— 0.8	+ 26 5
Nantes	S. 2 5	08.00 21.00	538	180 4	21	0.6	— 0.8	+ 0.4	94	11.9	— 0.2	— 6.6
Nantes	S. 4.2	08.10 21.30	538	180.4	84	4.5	— 0.2	— 3.0	93	15.7	— 1 0	+ 10.6
Nantes	S. 2.5	12.15	538	180.4	60	5.2	— 2.4	— 3.0	—	—	—	—
Nauen	S. 3.2	11.50	612	99.2	250	4.0	— 2.8	— 2.4	—	—	—	—
Nauen	C. W. 4.7	I	612	99.2	1421	87.0	— 2.5	+ 60.8	1471	78 2	— 0.8	— 40 4
Ongar (GLA).	C. W. 2.9	I	238	160.2	904	11.0	— 0 1	— 6 1	979	59.5	— 0.2	+ 30.0
Ongar (GLB).	C. W. 3.8	I	238	160.2	1239	7 5	— 0.8	— 9.1	859	34.4	— 1.2	— 17 4
Ongar (GLO).	C. W. 4.4	I	238	160.2	252	9.5	— 1.4	+ 5.7	321	23.9	— 1.7	— 13.0
Paris	S. 2.6	08.15	454	156.9	277	2.4	— 2.8	+ 1 4	—	—	—	—
Paris	S. 2.6	09.20 19.20	454	156.9	1486	5.5	— 3.1	— 3.8	432	5.8	— 2.7	— 4.0
Paris	S. 2.6	11.30 21.55	454	156.9	516	2.4	— 2 7	+ 1.3	162	13.2	— 4.0	— 7 0
Paris	S. 3.2	12.00	454	156.9	114	1 5	— 1.1	— 0.8	—	—	—	—
Poldhu	S. 2.8	09.50 21.50	374	205.6	42	2.9	+ 0.4	— 1.5	37	30 0	— 1 9	— 21.7
Sofia	S. 3.2	I	1,400	116.8	—	—	—	—	163	48.0	— 1 8	— 31.5
Whitehall	C. W. 3.3	09 00	247	164.9	43	6.9	+ 0.9	+ 4.3	37	7.1	+ 1.8	+ 3.8
Whitehall	C. W. 3.3	17.00 21.00	247	164 9	—	—	—	—	30	12 0	— 0 3	— 6.1

I = Irregular transmission.

TABLE III

Summary of Observations Taken at Orford from November 13, 1922 to March 29, 1924.

(1)	(2)		(3)	(4)	(5)				(6)			
					Day Observations.				Night Observations.			
TRANSMITTING STATION.	Type and wavelength.		Distance.	True bearing.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.	No.	Extent of variation.	Error of mean.	Maximum variation from mea
		meters.	(miles).	(degs.)		(degs.)	(degs.)	(degs.)		(degs.)	(degs.)	(degs.)
Amsterdam	S.	450	143	81.1	46	3.0	+ 0.6	— 1.7	9	1.0	+ 1.2	+ 0.7
Antwerp	S.	600	136	114.9	152	3.0	+ 0.5	+ 1.6	94	30.0	+ 0.9	— 15.8
Berwick	S.	450	285	332.0	161	2.5	+ 0.2	+ 2.3	106	20.0	+ 0.6	+ 12.4
Borkum	S.	450	237	62.3	65	3.0	+ 0.3	— 1.6	127	14.0	+ 0.1	— 7.4
Boulogne	S.	450	95	178.2	519	3.5	— 0.3	+ 2.1	341	15.0	0.0	+ 11.8
Cherbourg	S.	450	220	219.9	344	5.5	— 0.2	+ 2.8	294	90.0	+ 1.0	+ 59.1
Cullercoats	S.	600	236	330.0	142	4.0	— 0.3	— 1.7	110	45.0	+ 0.5	+ 24.5
Dieppe	S.	450	151	188.0	206	6.0	+ 0.4	— 3.4	—	—	—	—
Dunkirk	S.	450	83	154.1	294	3.0	+ 0.4	± 1.5	193	32.0	+ 0.9	+ 20.0
Dunkirk	S.	600	83	154.1	90	2.0	+ 0.4	± 1,0	85	15.0	+ 0.3	— 9.4
Flamborough	S.	450	155	334.8	331	2.5	— 0.4	— 1.4	258	45.0	— 1.5	— 28.3
Flushing	S.	450	98	116.0	936	4.0	+ 0.7	+ 2.3	173	30.0	+ 0.6	— 16.6
Grimsby	S.	600	123	328.0	149	4.0	— 0.5	+ 2.5	212	20.0	+ 0.8	+ 11.2
Havre	S.	450	188	200.0	977	5.5	— 0.6	+ 3.1	563	75.0	+ 1.5	+ 58.5
Havre	S.	600	188	200.0	25	3.0	— 0.6	— 1.6	—	—	—	—
Helder	S.	450	148	65.0	544	4.0	— 0.3	— 2.2	108	11.0	+ 0.2	+ 9.8
Lizard	S.	450	327	246.2	—	—	—	—	194	25.0	+ 2.7	— 13.9
Mok	S.	450	149	64.0	155	3.0	— 1.3	— 1.7	—	—	—	—
Niton	S.	600	161	230.5	81	5.5	— 4.3	— 3.2	40	20.0	— 4.6	— 15.9
North Foreland	S.	600	49.5	185.8	380	2.5	— 1.2	+ 2.4	404	15.0	— 1.2	+ 10.4
Ostend	S.	600	84	135.2	312	4.0	+ 0.1	+ 1.7	232	24.0	+ 0.1	+ 13.7
Parkeston Quay	S.	450	16.5	230.5	401	3.0	— 2.9	— 1.6	350	4.0	— 3.2	— 2.3
Parkeston Quay	S.	600	16.5	230.5	10	0.5	— 2.8	+ 0.3	10	1.0	— 2.9	— 0.6
Portland	S.	450	204	239.4	20	7.0	— 0.5	— 3.9	47	35.0	+ 7.6	— 22.0
Rochefort	S.	600	440	195.8	—	—	—	—	106	20.0	+ 2.8	+ 11.4
Scheveningen	S.	600	117	89.2	110	6.5	— 0.5	+ 3.8	52	25.0	— 1.1	— 13.1
Scheveningen	S.	1,800	117	89.2	139	5.5	— 0.4	— 3.8	68	35.0	— 0.3	— 18.9
Teddington	S.	450	93	240.6	712	4.5	— 2.6	+ 2.5	551	125.0	+ 1.7	+ 82.7
Teddington	S.	500	93	240.6	72	2.5	— 3.2	— 1.4	135	13.0	— 3.1	+ 12.5
Teddington	S.	750	93	240.6	129	2.5	— 3.1	— 2.0	498	25.0	— 2.7	+ 12.1
Teddington	I. C. W.	750	93	240.6	134	2.5	— 3.0	+ 1.9	264	17.0	— 2.7	+ 9.1
Teddington	C. W.	750	93	240.6	147	2.5	— 3.1	+ 1.5	444	20.0	— 2.4	+ 11.8
Teddington	S.	1,000	93	240.6	34	0.2	— 2.6	+ 0.2	101	0.5	— 3.0	+ 0.4
Teddington	I. C. W.	1,000	93	240.6	34	1.0	— 2.6	± 0.5	76	2.2	— 3.1	+ 2.2
Teddington	C. W.	1,000	93	240.6	134	2.0	— 2.5	± 1.4	221	10.0	— 2.1	+ 6.5
Teddington	S.	1,800	93	240.6	92	2.5	— 1.8	— 1.3	120	6.0	— 2.1	— 3.5
Teddington	C. W.	1,800	93	240.6	196	3.5	— 1.7	+ 2.1	328	30.0	— 1.4	+ 15.8
Teddington	C. W.	2,600	93	240.6	65	2.5	— 1.4	— 1.7	123	35.0	— 2.1	+ 21.5
Treguier St. Gonery	S.	450	307	224.9	15	3.5	— 2.6	— 2.3	12	13.0	+ 3.9	— 6.8
Ushant	S.	450	386	231.9	19	5.0	+ 0.2	+ 2.9	548	60.0	+ 2.0	+ 36.1
Wilhelmshaven	S.	450	293	67.8	304	4.0	— 0.6	+ 2.2	323	35.0	— 1.9	+ 19.1

maximum error is given as ± 180 deg. This indicates that a single minimum has been followed round the direction-finder scale through this angle and indeed on several occasions a rotation of the apparent bearing through more than 360 deg. has been observed. Instances of this effect are illustrated in figure 8. A somewhat similar phenomenon has been previously recorded by Wright and Smith (48), but on the much longer wavelength of 6,000 meters.

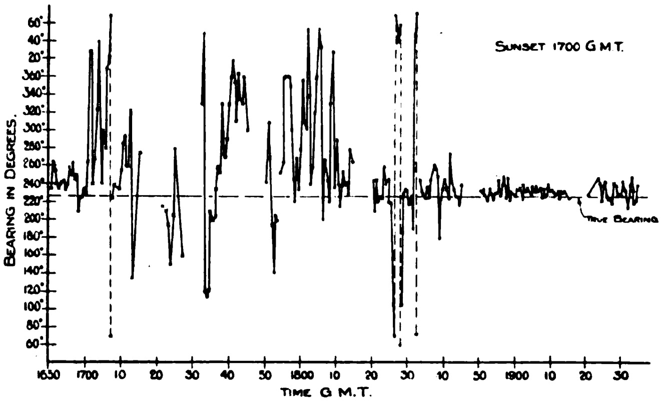

Fig. 8.

Graphs of Observed Bearings of Bournemouth (undamped waves, λ = 386 m) taken at Ditton Park, Slough. October 20, 1926.

Another mode of illustrating the variable errors due to night conditions is that adopted in figure 9. This diagram refers to records by several observers of the apparent bearings of Karlsborg during its daily transmissions from 2000 to 2030 on a wavelength of 2,500 meters. The observations were summarized in weekly batches and the graphs show the extremes of the bearings for individual weeks over a period of two years. It is very noticeable that the bearings show little variation so long as they are taken before sunset at the receivers, even though darkness has prevailed over a portion of the path of transmission for some time.

In spite of the large variations in apparent bearings described and illustrated above, it is noteworthy that during the night periods the observed bearings show no signs of a definite systematic error, and so the variations are on the whole equally distributed about the mean value. Another feature to be observed in connection with the magnitude of the night variations is the comparative rarity of the larger errors. A summary of the results obtained at Newcastle during the last year of operation is given in Table V, arranged in such a manner as to show the proportion of the observed bearings which differ by various fixed amounts from the mean day bearing. From this mode of expressing the results it will be seen that it is not often that more than 10 per cent of the night results give an error exceeding 10 deg. This fact, combined with the absence of a systematic error at night, is of great importance in the practical application of wireless direction-finding.

It thus appears that the chief effects to be ob-

TABLE IV.

Summary of Observations Taken at Slough from May 28 to December 17, 1925.

(1)	(2)	(3)	(4)	(5)				(6)			
TRANSMITTING STATION.	Wavelength.	Distance.	True bearing.	Day Observations.				Night Observations.			
				No.	Extent of variation.	Error of mean.	Maximum variation from mean.	No.	Extent of variation.	Error of mean.	Maximum variation from mean.
	(meters.)	(miles.)	(degs.)		(degs.)	(degs.)	(degs.)		(degs.)	(degs.)	(degs.)
Birmingham . .	479	88	319.1	201	3.0	+ 2.0	+ 1.9	1378	105.0	+ 3.4	− 67.5
Bournemouth . .	386	77	227.6	76	6.2	+ 0.4	+ 4.2	1346	>360.0	+ 5.3	±180.0
London. . . .	365	18	83.5	—	—	—	—	803	7.5	+ 1.3	− 4.8
Newcastle . . .	404	245	350.2	—	—	—	—	537	75.0	− 1.4	+ 51.4

(The transmissions were all on telephony on which the carrier wave was treated as C. W. for reception purposes.)

TABLE V.

Showing Percentage Variations of Bearings from the Annual Mean at Newcastle, 1922-23.

(1)	(2)		(3)	(4)		(5)		(6)		(7)		(8)	
TRANSMITTING STATION	Type and wavelength		Time of transmission	Total number of observations		Percentage Variations from Annual Mean							
						Over 2 deg.		Over 5 deg.		Over 10 deg.		Over 20 deg.	
		(km)		Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Aberdeen	C.W.	3 3	08.30 17 00	189	125	37.0	63.1	6.3	28.0	0.5	13 6	0.0	0.0
Aberdeen	C.W.	3.3	21.00	—	111	—	82.0	—	49.5	—	10.1	—	0 0
Air Ministry	C.W.	4.1	I	247	252	17.0	33.3	0.8	8 3	0 0	1.6	0 0	0.0
Berne	C.W.	3.4	I	530	217	3.2	61.3	0.4	32.7	0.0	10 6	0.0	1 8
Budapest	S.	3.0	I	48	26	2.1	15.4	0.0	0.0	0.0	0.0	0.0	0 0
Chelmsford	C.W.	3.8	I	76	70	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cleethorpes	C.W.	4.3	08 00	118	—	30.5	—	2.5	—	0.0	—	0.0	—
Cleethorpes	C.W.	4.3	I	116	187	12.9	61.0	0.0	13.9	0.0	0.5	0 0	0 0
Clifden	S.	5.8	09.05 21.50	85	66	0.0	28.8	0.0	9.1	0.0	0.0	0.0	0.0
Clifden	C.W.	5.8	I	316	594	0.0	6 9	0.0	3.4	0.0	1 2	0.0	0.0
Coltano	S.	4.2	I	169	244	1.0	16.4	0.0	1.0	0.0	0.0	0.0	0.0
Horsea	C.W.	5.0	I	193	98	23.8	39 8	2 6	10.2	0.0	0.0	0.0	0 0
Karlsborg	S.	2.5	12 15 20.00	171	485	20.5	83 5	0.0	42.5	0 0	20.2	0.0	1.9
Karlsborg	S.	4 2	I	125	53	6.4	50.9	0.0	18.9	0 0	7.5	0.0	0.0
Karlsborg	C.W.	3.9	I	503	237	11 3	40.0	0.6	16.9	0.0	8 5	0·0	2 1
Konigswusterhausen	C.W.	5.2	I	501	260	14 2	49.6	0 0	18.1	0.0	4.2	0 0	0 4
Moscow	S.	4.8	I	421	945	5.0	21.9	0.0	6.6	0 0	1.7	0.0	0.2
Nantes	S.	2.5	08 00 21 00	21	94	0.0	26.6	0.0	5.3	0.0	0.0	0.0	0.0
Nantes	S.	4.2	08 10 21.30	84	93	2.4	35.5	0.0	8.6	0.0	1.1	0.0	0.0
Nantes	S.	2.5	12 15	60	—	6.7	—	0.0	—	0.0	—	0.0	—
Nauen	S.	3 2	11.50	250	—	2.0	—	0.0	—	0 0	—	0.0	—
Nauen	C.W.	4.7	I	1421	1471	17.7	52.7	6.8	23.9	2.2	5 9	0 3	0.6
Ongar	C.W.	2.9	I	904	979	19.3	50 2	0.1	24.9	0.0	5.9	0.0	0.6
Ongar	C.W.	3 8	I	1239	859	2 1	34.7	0.1	14.8	0.0	2.7	0.0	0.0
Ongar	C.W.	4.4	I	252	321	4 7	24 0	0.4	10.6	0.0	1.6	0.0	0.0
Paris	S.	2.6	08.15	277	—	0 0	0.0	0 0	0.0	0 0	0.0	0.0	0.0
Paris	S.	2 6	09 20 19.20	1486	432	3.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Paris	S.	2.6	11.30 21.55	516	162	0.0	23 4	0 0	2.5	0.0	0.0	0.0	0.0
Paris	S.	3.2	12 00	114	—	0.0	—	0.0	—	0.0	—	0.0	—
Poldhu	S.	2.8	09 50 21 50	42	37	0.0	65.0	0 0	27.0	0 0	8.1	0.0	5.4
Sofia	S.	3.2	I	—	163	—	45.4	—	16.5	—	3.7	—	0.6
Whitehall	C.W.	3.3	09 00 17.00	43	37	30.2	46.0	0.0	0.0	0.0	0.0	0.0	—
Whitehall	C.W.	3.3	21.00	—	30	—	40 0	—	10.0	—	0.0	—	0.0

served in radio direction-finding are generally as follows. In the summer time in those latitudes in which the United Kingdom is situated the observed bearings in daylight are fairly constant and, with the exception of the permanent errors already mentioned, they approximate quite accurately to the true geographical bearing of the transmitting station. Under certain conditions of transmission to be referred to below this accuracy is maintained at all times and seasons. When these conditions do not prevail, however, the observed bearings show signs of variable errors as the setting of the sun approaches the path of transmission. These variations then prevail throughout the night, but decrease to a negligible extent soon after sunrise. As the seasonal conditions are changed gradually from summer to winter the variations in the daytime increase somewhat; and the night conditions begin an appreciable time before sunset and continue until some time after sunrise. In the midwinter conditions represented by January, the change from day to night effects is very much more gradual and the difference is only distinguishable by the difference in magnitudes of the variations. At this time of year it appears that on the longer wavelengths the variations may have an amplitude of the order of 10 deg. or more during the daylight hours, and this increases rapidly at about one hour before sunset to the night value of 50 deg. or 70 deg., and so continuing in the most erratic manner until one hour or so after sunrise.

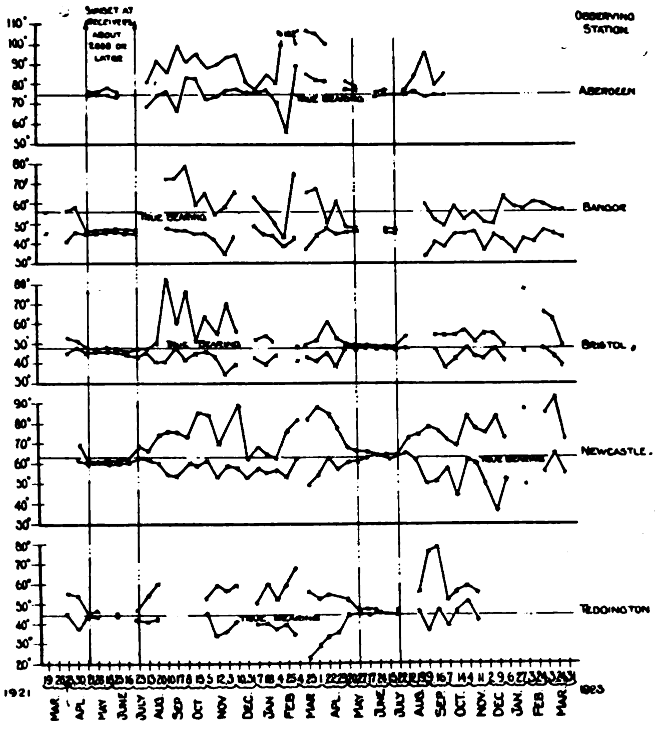

FIG. 9.

Graphs of Weekly Extreme Bearings of Karlsborg (damped waves, λ = 2.5 km) observed on the transmissions at 2000 G. M. T. during the two years, March, 1921 to March, 1923.

It has now been satisfactorily established that these variations in apparent bearing are due to the arrival at the receiver of waves from the upper atmosphere polarized with their electric force in a horizontal plane. This explanation was first put forward by T. L. Eckersley (49) in 1921 and supported by experimental results. Of recent years considerable direct confirmation of the theory has been provided (50, 51, 52), and the study of the propagation of electromagnetic waves through the ionized regions of the atmosphere now forms the subject of large numbers of papers published in all parts of the world.

B) *Effect of Various Factors upon Variations in Bearings.* — From time to time throughout the investigation the results have been carefully considered of ascertain if there is any definite relation between the wavelength of transmission and the nature, frequency, and magnitude of the variations in apparent bearings experienced. Over the band of wavelengths from 300 to 20,000 meters no marked difference has been observed in the extreme variations recorded, after due allowance has been made for the distance and the geographical conditions over the path of transmission. The outstanding exception to this statement is the case of Bournemouth observed at Slough, as mentioned above, in which exceedingly violent variations have been recorded. It is probable that this occurrence is due to a coincidence of wavelength and distance, and the relative magnitudes of the downcoming and direct waves. The conclusion that, within wide limits, the wavelength has no effect upon the amplitude of the variations observed over a period is to be distinguished from the fact that when the wavelength of transmission is changed instantaneously the error in bearing due to night effect also changes appreciably. Excellent examples of this occurrence have been obtained in observing on the transmissions from arc stations, such as Leafield, which employ for signalling purposes a marking and spacing wave differing in length by about 1 per cent. The errors in bearing taken in rapid succession on the marking and spacing waves differed at times by 20 deg. to 30 deg.

The experience of the author obtained in Great Britain that the wavelength itself does not have a very marked effect upon the magnitude of the variations would appear to differ from that a Austin (53), who states that in the United States of America the variations on the shorter wavelengths are considerably less than on the longer wavelengths. This conclusion does not, however, appear to be consistent with the results obtained by Merritt (54), Bidwell (55), and Reich (56) at Cornell University, which show variations in bearings exceeding 100 deg. on wavelengths of 380 to 500 metres. The difficulty of drawing very definite conclusions from observations made on available transmissions from commercial stations within range is illustrated by Table VI, which is intended to show the decrease in magnitude of the bearing variations when the range of transmission is over 3,000 miles. The results given in this table were obtained at Teddington, England, during a series of continuous tests each lasting 24 hours, in which observations were made of the apparent bearings of various European and American stations transmitting on wavelengths between 14,000 and 19,000 meters. These experiments have shown that over similar distances the variations experienced on the wavelengths 2,000 to 9,000 meters are of the same order as those on the higher wavelengths, and also that the actual amplitudes of the variations decrease considerably for a range of transmission exceeding 3,000 miles. In fact, on the American transmitting stations the variations in bearings show no marked distinction between day and night periods. As illustrated in Table VI, observations taken over several 24-hour periods show a maximum error in bearing of about 3 deg. for the American stations, while on nearer European stations the night error may range up to nearly 30 deg. From Table VI it is seen that of the two American stations observed one gave 94 per cent and the other 100 per cent of bearings correct within 2 deg. during the whole series of tests; whereas of the European stations the best example, Carnarvon, gave only 63 per cent of bearings correct to within this limit. The contrast of the observations on the stations at different distances is illustrated by figures 10 and 11 which are typical of the results obtained on transmissions from the American and European stations. The

TABLE VI.

Summary of Observations Taken at Teddington during 24-hour Test from January to June, 1926.

(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)			
TRANSMITTING STATION.		Wavelength.	Distance.	True bearing.	No. of observations.	Extent of variation.	Error of mean bearing.	Maximum variation from mean.	Percentage of Bearings differing from Mean by more than :			
									2 deg.	5 deg.	10 deg	20 deg.
		(meters.)	(miles.)	(degs.)		(degs.)	(degs.)	(degs.)				
Bordeaux	LY. . .	18 940	452	181.8	316	33 0	— 0.2	— 19.1	63.3	32.6	5.4	0.0
Carnarvon	MUU. . .	14 200	200	307.3	139	7.7	+ 1.3	— 4.6	36.9	0.0	0.0	0.0
Karlsborg	SAQ. . .	18 050	760	44.4	219	19.8	+ 2.9	— 11.6	55.7	11.9	0 9	0.0
Long Island	WQK. . .	16 460	3,403	287.9	547	7.4	+ 2.3	+ 3.4	6.4	0.0	0.0	0.0
Rugby	GBR. . .	18 900	75	330.4	147	34.5	— 1.3	+ 27.9	85.8	47.7	11.6	4.8
St. Assise	UFT. . .	14 290	237	146 3	416	34.0	— 3.9	— 22.4	83.7	35.4	9.4	0.3
Tuckerton	WCI. . .	16 800	3,521	287.3	192	3.7	+ 2.4	+ 2.0	0.0	0.0	0.0	0 0

error of the daylight readings is in each case attributable to local conditions at the direction-finder.

While discussing the effect of distance on the errors in observed bearings it may be mentioned that Pickard (57) published in 1922 some results, of which a very noticeable feature was that the apparent bearings of European stations observed at Maine, U. S. A., showed much smaller variations than the bearings of some American stations. This difference was attributed to the fact that the transmission from the former was mostly over sea, whereas in the latter case it was entirely over land. It can be shown from theoretical considerations, however, that this is probably not the correct explanation (16*d*). Mesny (58) has also found that the bearings on some American stations observed in France show only a very small variation as compared with bearings taken on the nearer European station. Experiments carried out in Shanghai by Gherzi (59) during 1923-24 have also shown that while large night errors are observed for distances of transmission of less than 5,000 km. (3,000 miles) these errors have an extreme value of about 6 deg. when the range of transmission is from 5,000 to 12,000 km (3,000 to 7,500 miles).

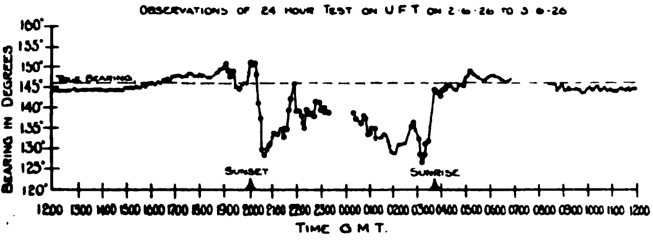

FIG. 10.

Graph of Observed Bearings of Long Island (WQK, λ = 16.5 km) taken at Teddington during a 24-hour period, January 13 to 14, 1926.

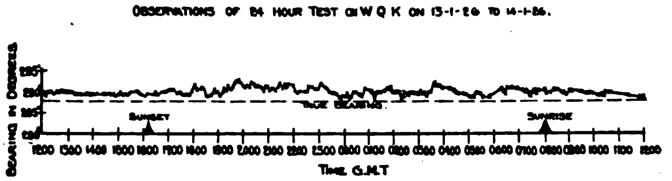

FIG. 11.

Graphs of Observed Bearings of Ste. Assise (UFT, λ = 14.3km) taken at Teddington during a 24-hour period, June 2 to 3, 1926.

The effect of the incidence of sunlight upon the upper regions of the earth's atmosphere can also be demonstrated during a solar eclipse. Figure 12 shows the results of observations made at Slough on the transmissions from the Manchester broadcasting station during the solar eclipse of June 29, 1927. Although the normal night variations had ceased at about one hour after sunrise, it is seen that variations were temporarily restored during the period of obscuration of the sun. A discussion of these and other wireless observations made during the eclipse will be found in the official published report (60).

In concluding this section it may be repeated that it is only intended to be a general summary of the results obtained from the co-ordination of a large quantity of data. Anyone who is interested in obtaining more exact information on any portion of the work may be referred to the official reports containing the tabulated results in detail and published by the Radio Research Board. As far as the actual nature and magnitude of the effects observed are concerned, the author believes he is correct in stating that his results obtained in the British Isles are in complete agreement with the observations made in other countries, such as by Mesny and others in France (58, 61, 62), by Stoye in Germany (63), Austin (64), Bidwell (54, 55), and Pickard (57) in America; and by Gherzi (59) in China.

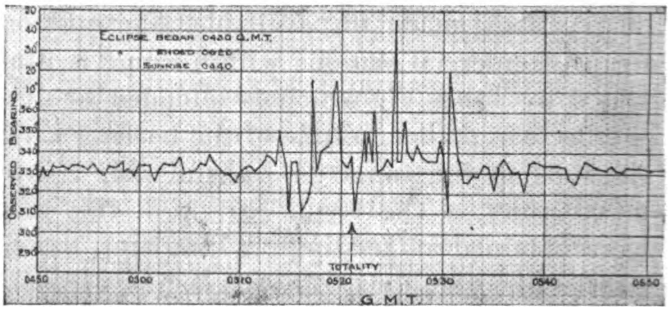

FIG. 12.

Observations of Apparent Bearings of Manchester (2ZY) at Slough during the Solar Eclipse, June 29, 1927.

4. Analysis of the Performance of a Rotating Beacon.

If the application of the principle of reversibility in direction-finding as stated in Section 2 be accepted, then it is evident that the performance of a rotating loop beacon transmitter can be largely predicted from the results and experience obtained with receiving loop direction-finders. Thus a rotating loop beacon when erected on the same site as a direction-finder will give bearing observations at a distant receiver, which will be subject to the same type of local error and night variations, for example, as the bearings observed on the direction-finder when the distant receiving aerial is used for transmission. Such deductions as these have been confirmed by the author during the past two or three years in the investigation of the performance of a rotating beacon erected at Fort Monckton, near Gosport, England (44). Bearings observed on this beacon in certain directions were found to be subject to a small permanent error, which was of an approximately quadrantal nature, and which decreased in magnitude with increase of the working wavelength (46). This error was of the same order as that experienced with a wireless direction-finder set up in proximity to the beacon, and was found to be most probably due to some underground power cables. In the choice of sites for future beacons it is evident that a portable direction-finder can be usefully employed in ascertaining the suitability of the site and its liability to produce local errors.

In order to ascertain the reliability of this type of rotating beacon as an aid to marine navigation, a number of tests were carried out on ships crossing the English Channel between Southampton and Havre, and Southampton and Jersey. Using the ship's ordinary wireless receiver observations of the bearing of the beacon were made at intervals during each trip and compared with the bearing as given by the Captain of the ship.

A typical log of one of these tests is given in Table VII, while the chart in figure 13 shows a

TABLE VII

Summary of Observations Obtained on a Return Voyage from Southampton to Havre, September 22 to 24, 1926.

Continuous Wave Transmission, λ = 525 m.

DATE.	G. M. T.	From information supplied by Captain of ship.			Wireless bearing from beacon.	Remarks.
		Position and how obtained.	From Fort Monckton.			
			Distance.	Bearing.		
			(miles.)	(degrees.)	(degrees.)	
22 September 1926.	2240	Southampton. A. . .	14 3	127	126	Mean of several readings.
23 September 1926.	0102	Beyond Nab. V. B. .	17.5	324	323	
	0132	D. R. .	26.0	328	329	
	0202	D. R. .	35	330	331	
	0232	D. R. .	43	331	331	
	0302	D. R. .	51	332	332	
	0332	D. R. .	60	333	334	
	0532	D. R. .	85	335	335	
	0602	D. R. .	94	334	335	Night effect observed.
	0632	D. R. .	96	330	331	
	0722	Havre. A. . .	105	328	330	
	1702	Havre. A. . .	105	328	329	Mean of several readings.
24 September 1926.	0012	D. R. .	95	330	331	
	0032	D. R. .	88	330	329	Night effect observed.
	0102	D. R. .	79	329	327	
	0132	D. R. .	69	329	325	Night effect observed.
	0202	D. R. .	60	329	325	
	0232	D. R. .	52	329	325	
	0402	D. R. .	24	329	326	
	0432	V. B. .	15	325	326	
	0442	2 miles from Nab. V. B. .	11.5	324	323	

Notes. — (1) A = moored in dock, V. B. = visual bearings, D. R. = dead reckoning. (2) Night effect observed at 60 miles and over. (3) Maximum difference between estimated and observed bearings = 4 deg. at night. (4) Sea moderate throughout.

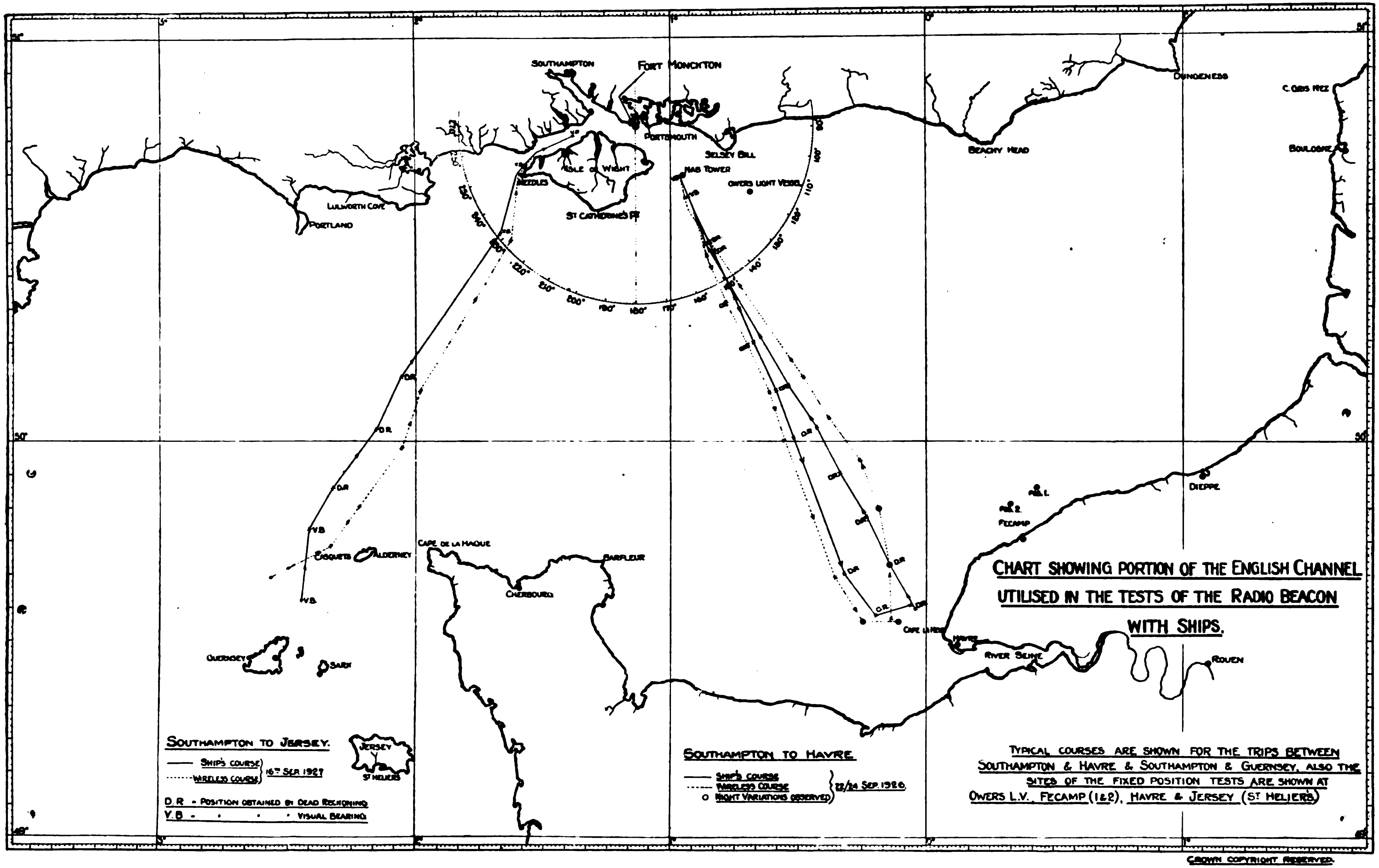

FIG. 13. — Chart Showing Portion of the English Channel Utilized in the Tests of the Radio Beacon with Ships.

comparison between the ship's « dead reckoning » and the wireless course in three other tests. As a results of tests conducted on these lines it was found that in the majority of cases the estimated and observed bearings agreed within from 2 deg. to 4 deg., although at times this difference ranged up to 12 deg. Signs of night effects in the shape of indistinct signal minima and wandering bearings were observed at distances exceeding 50 miles, but these were not always coincident with the above differences which sometimes occured in daylight. In many cases at night and during misty weather, when visibility was very poor, the ship had to be navigated by dead reckoning so that the estimated bearing of the beacon from the ship may be subject to some suspicion.

In order to study these night variations in a more satisfactory manner, a number of tests were arranged in which observations were made continuously over a period of twelve hours or more from various fixed positions. The places of observation were selected so as to provide a variety of ranges and also to show the difference between transmission over sea and over land. Some of the observations were carried out in ships moored in dock or alongside a light vessel, while other observations with transmission entirely overland were carried out at Slough and Teddington.

An analysis of the readings obtained in this manner in daylight shows that for ranges up to 56 miles the maximum departure of the observed bearings from their mean or correct value was 3 deg., while up to the maximum range of 119 miles the greatest deviation was 6 deg. In most cases over 90 per cent of the observations were correct within 2 deg. When the observations were carried out at night, the above accuracies were maintained for distances overland of 14 miles and oversea of 23 miles. At distances of 92 miles entirely oversea the night errors experienced ranged up to a maximum value of 18 deg., but it is to be noted that in these cases over 84 per cent of the bearings were correct to within 5 deg. When the oversea distance exceeded 100 miles the errors became more serious. For overland transmission the errors were much larger, and at a distance of 55 miles errors up to 32 deg. were experienced, while only 66 per cent of the observed bearings were correct to within 5 deg. In spite of such large errors, however, it was found that the mean bearing of the beacon from any position was practically the same by day or night. This implies that the systematic error of the night variations is very small, so that the effect of errors of individual observations can be largely mitigated by taking the mean of a number of successive bearings. It was not found possible to draw any definite distinction between the use of continuous wave and interrupted continuous wave transmissions.

Owing to the difficulty of anchoring a ship in a fixed position at a considerable distance from land for a period of 12 hours or more, it has not been possible to fill in the gap which occurs in these tests between distances of 23 and 92 miles, all oversea. No evidence of night effect was observed in the cross-channel tests at any distance below 60 miles, however, and it seems reasonable to infer therefore that the reliability of the bearings at 23 miles as recorded above would be maintained up to distances of 50 or 60 miles so long as the path of transmission is entirely oversea. Under these conditions we may expect that about 85 per cent of all observed bearings will be correct to within 2 deg. At larger distances night errors begin to be encountered but do not become serious until the oversea range is in excess of 90 miles.

This conclusion may be compared with the somewhat similar one contained in the following quotation from a paper (65) by the author, describing experiments made a few years ago to test the reliability of wireless direction-finding oversea.

> When, however, the transmission is entirely oversea, so as to be well clear of any land effects, the accuracy of observed bearings is maintained within the limit of 2 deg. for night as well as for day working at distances approaching 60 miles ; and even up to 100 miles over 90 per cent of the bearings are correct within 2 deg., the limiting error under ordinary working conditions being 4 deg.

Such accuracies refer to the bearings obtained at a *land* direction-finding station; and are superior to those obtainable with a ship direction-finding installation, a matter which is discussed in Section 6 below.

COMPARISON OF BEARING OBSERVATIONS BY BEACON AND BY DIRECTION-FINDER

With a view to obtaining experience on the relative merits of the rotating beacon and the direction-finder as a means of obtaining wireless bearings, a direct comparison of the two systems has been carried out under a variety of conditions.

At each site a simple receiver with a vertical aerial was employed for the reception of the signals from the rotating beacon. Adjacent to this, but at a sufficient distance to avoid mutual interference, a single-frame coil direction-finder was set up for the purpose of taking ordinary direction-finding bearings while the beacon loop was fixed with its plane approximately in the direction of the receiver. As a further precaution against producing a spurious reading on the direction-finding set the vertical aerial was disconnected during the taking of bearings on the direction-finder. A few tests carried out on land showed that apart from the occurrence of local errors due to the site selected, the two systems gave observed bearings of similar accuracy. In order to study the variations in bearings experienced with the two systems over extended periods, further experiments were carried out on a ship at Jersey and on land at Slough. The analysis of a large number of readings taken in this manner confirmed the similarity in accuracy of the two systems, and showed also that results obtained with continuous wave transmission were similar to those obtained with interrupted continuous waves.

At night time the variations in observed bearings were quite serious in all cases. The extent of the variation ranged from 20 deg. to 57 deg. in the case of the rotating beacon bearings, and from 69 deg. to 130 deg. in the case of the direction-finding bearings. Under these conditions, however, over 86 per cent of the bearings taken on the rotating beacon were in error by less than 10 deg. while in the case of the direction-finding bearings over 62 per cent were in error by less than 10 deg. As already mentioned it is now well-known that these errors are due to the reception of waves from the transmitter deflected in the upper atmosphere, and it is realized that in the results quoted above the variations on the direction-finder are exaggerated by the fact that the loop transmitter radiates very much more to the upper atmosphere than is the case with a vertical aerial.

COMPARISON TEST AT SEA

Some of the test runs made on ships between Southampton and Jersey, discussed above, were carried out in a ship which is fitted with a Marconi direction-finder using fixed frame coils on the Bellini-Tosi system; and the opportunity was thus provided of comparing the two systems of obtaining wireless bearings under actual seagoing conditions. The results obtained on one trip, in which observations were made successively on the rotating beacon and on the direction-finder with the beacon fixed in the maximum signal position, are given in Table VIII.

Considering first the results in Table VIII it is seen that with two exceptions the direction-finding bearings agree with the estimated bearings to within 5 deg. Of the two exceptions, one shows an error of 10 deg. at a range of 114 miles, while the second shows an error of 11 deg. at 14 miles distance, when the ship was proceeding up the Solent. It is thought that a portion of these errors, but probably not more than 3 deg. or 4 deg., is due to a land deviation effect which is difficult to compensate for on a ship direction-finding set. During the same run, the rotating beacon bearings, after correction for the 1 deg. or 2 deg. of error in some positions from the calibration curve, show a maximum departure from the estimated bearing of 4 deg.

In searching for an explanation of the direction-finding errors above, it is to be remembered that the direction-finding bearing is observed relative to the ship's head and that, therefore, the accuracy of the bearing is limited to the accuracy with which the ship's compass indicates the *instantaneous* direction of the ship's head. On the ship in question the direction-finding set is operated from the wireless room and on a signal being given to the bridge the compass reading is taken by one of the ship's officers. In anything but a very calm sea it is naturally difficult to keep the ship's head steady to within one or two degrees, and in a rough sea the swing may amount to five degrees or more. Also there is probably a lag between the actual direction of the ship's head and the reading of the compass. Finally, unless it is calibrated at frequent intervals, it is doubtful if the reading of a magnetic compass is accurate to within 2 deg. or 3 deg. over all parts of the scale. The considerations may result in the accuracy of a ship direction-finder installation being appreciably inferior to that of a similar apparatus on land. The errors due to the above cause will probably decrease with an increase in the size of the ship, but the ship mentioned above is probably typical in size to many which will, in the future, utilize wireless bearings for navigation. It is also to be remarked that the ship direction-finding set is subject to a quadrantal error, for which correction or compensation is necessary.

On the other hand the rotating beacon method of obtaining wireless bearings is free from all these objections. Except for the interfering effects of noise and general vibration, the accuracy of the observed bearings is the same whether the ship is in dock or at sea.

RECEPTION OF BEACON TRANSMISSIONS ON LOOP AND AERIAL

Since it may sometimes be required to receive and observe signals from a rotating beacon on a closed loop or direction-finding set instead of on an open aerial, it was considered to be useful to make a brief comparison between the two cases.

TABLE VIII.

Summary of Observations Obtained of a Return Trip between Southampton and Jersey, September 14 to 16, 1927.

DATE.	G. M. T.	From information supplied by Captain of ship.				Wireless Bearings		Type of transmission.	Remarks.
		Position and how obtained.		From Fort Monckton.		from beacon.	by D. F.		
				Distance.	Bearing.				
				(miles.)	(degs)	(degs.)	(degs.)		
14 September 1927.	2340	Off Egypt Point.	V. B.	9	90	92	88	I. C. W.	
15 September 1927.	0010	Off Yarmouth Pier.	V. B.	16	78	74	75	C. W.	
	0040	nr. Needles.	V. B.	22	68	65	67	I. C. W.	Sea rough.
	0610	At Guernsey.	A.	110	34	36	33	C. W.	
	0710	St. Martin's Point.	D. R.	111	31	34	33	C. W.	
	0740	nr. Groznez Point.	V. B.	114	27	30	37	I. C. W.	
	1540	At Jersey.	A.	116	21	22	26	I. C. W.	Means of several readings.
	1610	At Jersey.	A	116	21	22	24	C. W.	
	1640	At Jersey.	A.	116	21	22	25	I. C. W.	
16 September 1927.	0710	nr. La Corbière.	V. B.	119	25	28	Sigs. too weak.	C. W.	Sea smooth.
	0940	nr. Casquets.	V. B.	96	35	39	36	I. C. W.	
	1010	beyond Casquets.	V. B.	88	39	36	36	C. W.	
	1040	49°54′ N. 2°17′ W.	D. R.	78	40	38	42	I. C. W.	
	1110	50°2′ N. 2°9.5′ W.	D. R.	68	41	38	41	C. W.	
	1140	50°9.5′ N. 2°2.5′ W.	D. R.	55	43	39	41	I. C. W.	
	1310	Outside Needles.	V. B.	30	52	48	57	C. W.	
	1340	Inside Needles.	V. B.	20	71	70	71	I. C. W.	
	1410	Lepe Middle.	V. B.	14	82	82	93	C. W.	
	1440	Beacon Buoy.	V. B.	10	119	121	119	I. C. W.	

Notes. — (1) A = moored in dock, V. B. = visual bearing, D. R. = dead reckoning. (2) Maximum difference between estimated and observed bearings on beacon = 4 deg. in daylight. The observed bearings have been corrected for land errors in accordance with the previous calibration of the beacon in the area occupied by the ship. (3) Maximum difference between estimated and D. F. bearings = 11 deg. in daylight. Part of this difference is probably due to land effects for which a correction is not readily applicable.

When working in daylight or under such conditions at night as to be from night variations, it has been found that the bearings observed on a loop agree with a maximum departure of one degree, with those observed on an aerial. When operating under conditions of night variations, however, the errors encountered on the loop receiver are greater than those observed on the aerial. This effect is due to the fact that with downcoming waves arriving at the earth's surface the resultant horizontal magnetic field (operating on the loop) is of greater intensity than the vertical electric field (operating on the vertical aerial) (50, 52). These results have been confirmed for both continuous wave and interrupted continuous wave transmission.

Night Errors Experienced Under Strictly Reversible Conditions

Reference has been made in one or two places in this paper of the application of the reciprocal theorem to wireless direction-finding. While the form of comparison of the rotating beacon and the direction-finder adopted in the tests described above is the correct one for determining the relative advantages of the two systems for marine navigation purposes, it does not constitute a strict reversibility of the system, aerial to loop. By erecting a direction-finder in close proximity to the rotating beacon and using a distant aerial either to transmit to the dierction-finder or to receive from the beacon this reversibility is achieved. In this manner it was shown that both local and night errors are of the same order on the two systems and a graph of bearing taken at night under these conditions is shown in figure 14.

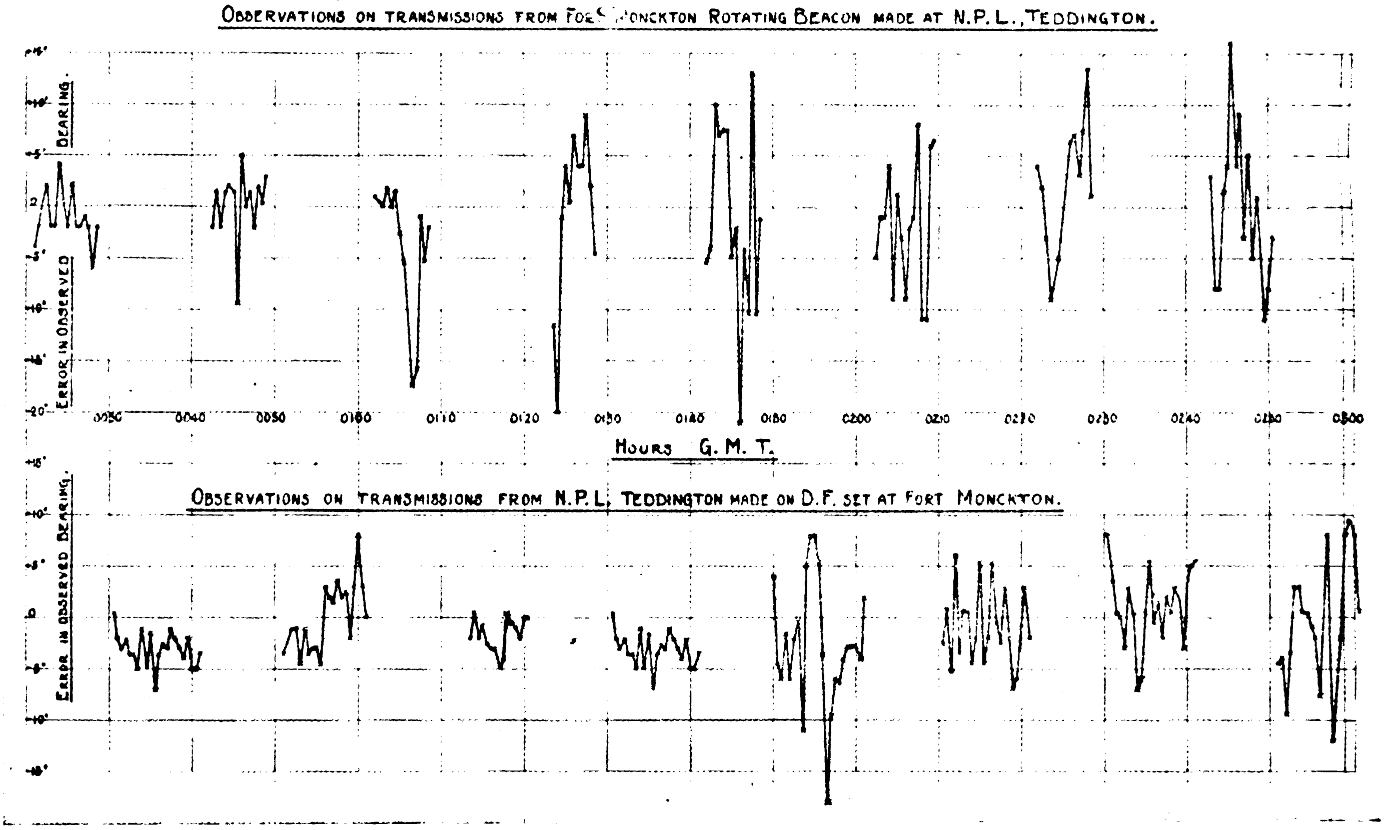

Fig. 14.
Comparison of Night Observations on Rotating Beacon and on Direction Finder, March 22, 1928 (undamped waves, λ = 525 meters).

5. Conditions Affecting Direction-Finding as an Aid to Navigation.

In the application of a direction-finding system to either marine or aerial navigation it is important to understand clearly the exact conditions under which the observed bearings are accurate, and in other conditions to appreciate the order of magnitude of the possible errors involved and the means of mitigating these where possible. It is generally conceded nowadays that an accuracy of 2 deg. in observed bearings is suitable for navigation purposes, particularly when it is borne in mind that the observations may be repeated at frequent intervals.

An important factor to be noted from a navigational point of view is that of any effect of fog on direction-finding, since it is chiefly during foggy weather that the majority of direction-finding stations are called into action On several occasions the author has taken particular notice of the existence of fog at times when observations were in progress with a negative result. On one occasion in particular the fog was spread over the British Isle and a large portion of Western Europe, but the directional variations showed nothing beyond the usual day and night effects. These results form a confirmation to the observations of Rothé (66), who concluded that no variations in ordinary atmospheric conditions would account for the small variations in bearings observed in the daytime.

During the course of the many experiments carried on with the direction-finder and the rotating beacon it has been found that the type of wave transmission employed has no effects upon the bearings observed, and that the errors and effects encountered are of the same order for damped, undamped, and interrupted undamped waves (67, 44).

A) *Errors Due to Local Conditions.* — In Sections 2 and 3 above it has been mentioned that various conditions may be present in the neighborhood of either a direction-finding station or a rotating beacon to cause an error in the bearing observed on a distant station. From various detailed investigations into the causes of such errors it is known that the most prominent effects are due to masses of metalwork and wires, either above or below the earth's surface, and to trees (19, 20). In most cases where the directional station is situated on land it is possible to select a site which is largely if not entirely immune from such effects, and provided that the residual errors do not exceed 2 deg. or 3 deg. in magnitude they can be definitely ascertained by a calibration at short distances, and a correction obtained for application to other observed bearings. In the case of the use of a direction-finder on board ship it is impossible to be clear of the metalwork of the ship itself and the resulting bearings are subject to a quadrantal error, which can either be compensated by circuit adjustment or corrected for from a chart (41, 42, 43).

B) *Coastal Errors.* — Another type of error (which might be classified as one due to local conditions, but which, on account of its importance in the application of direction-finding to marine navigation deserves a special section) is that due to the deviation of wireless waves in crossing a coast-line, when the path of the waves lies approximately parallel to the coast. In the experimental work carried out at Orford, Suffolk, the coastal error on wavelengths of 450 and 600 meters was found to be of the order of 3 deg. or 4 deg. when the direction of transmission was within 20 deg. of the coast-line. In one instance, in which the wavelength was systematically increased from 500 to 2,600 meters, the corresponding error decreased from 3.2 deg. to 1.4 deg. On higher wavelengths the observed coastal error was less than one degree. In every instance the error was such as to indicate a bending of the waves towards the normal to the coast-line, in passing from the sea to the land side of the boundary. These experimental results are in complete agreement with those previously obtained by Eckersley (8) but, as already pointed out (68), they are inconsistent with the explanation of the deviation as a coastal refraction effect due to the difference in the superficial velocity of wireless waves over land and sea. For the theoretical aspect of the problem would appear to indicate a deviation much smaller than that actually observed, and also in the opposite direction.

More recently some experiments on the propagation of waves across a coastal boundary have been made by Baümler and Zenneck (69). Their results generally confirm those given above as to the magnitude and direction of the deviation of the waves in passing from sea to land. They further showed that the deviation at the coast is unaltered by the change in sea-level from high to low tide. Worlledge (70) has also given brief details of some experiments carried out at a direction-finding station in which indications were given of the reflection of wireless waves from the landward side of a coastal boundary. As a result of this phenomenon errors in observed bearing and indistinct minima due to interference may be produced at a direction-finding station when observing on transmissions emanating from a station on the same side of the boundary.

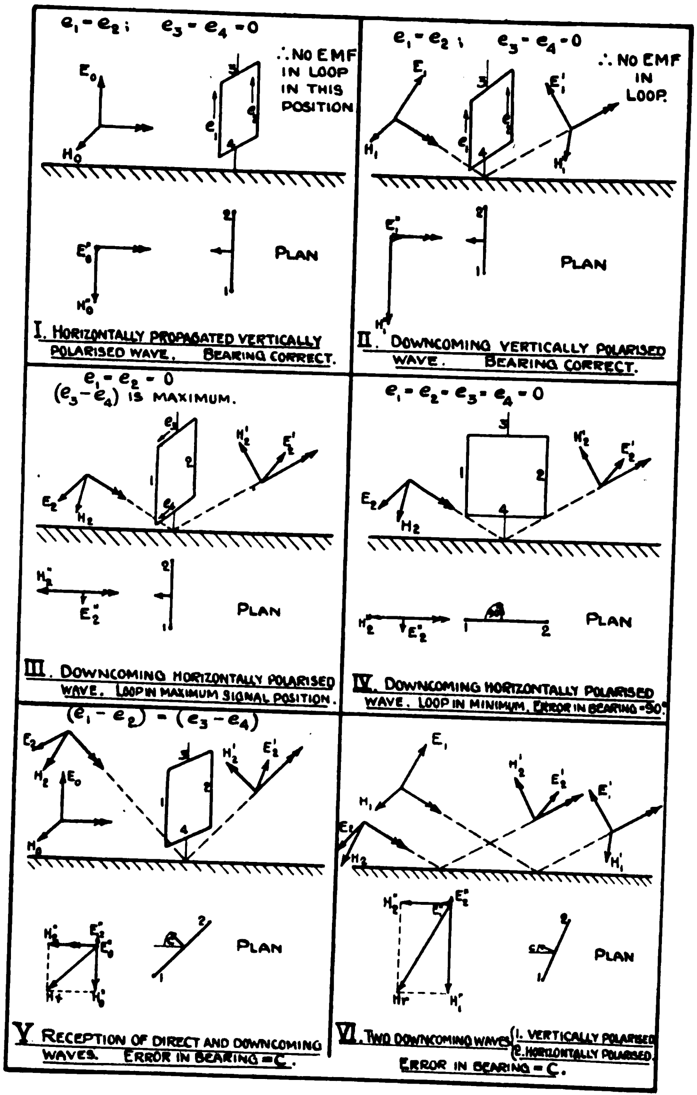
e₁ - e₂ ; e₃ - e₄ = 0
∴ NO EMF IN LOOP IN THIS POSITION
E₀
H₀
PLAN
I. HORIZONTALLY PROPAGATED VERTICALLY POLARISED WAVE. BEARING CORRECT.
e₁ - e₂ ; e₃ - e₄ = 0
∴ NO EMF IN LOOP
E₁
H₁
PLAN
II. DOWNCOMING VERTICALLY POLARISED WAVE. BEARING CORRECT.
e₁ - e₂ = 0
(e₃ - e₄) IS MAXIMUM.
E₂
H₂
PLAN
III. DOWNCOMING HORIZONTALLY POLARISED WAVE. LOOP IN MAXIMUM SIGNAL POSITION.
e₁ = e₂ = e₃ = e₄ = 0
E₂
H₂
PLAN
IV. DOWNCOMING HORIZONTALLY POLARISED WAVE. LOOP IN MINIMUM. ERROR IN BEARING = 90°
(e₁ - e₂) = (e₃ - e₄)
E₂
E₀
H₀
PLAN
V RECEPTION OF DIRECT AND DOWNCOMING WAVES. ERROR IN BEARING = C.
E₁
H₁
PLAN
VI. TWO DOWNCOMING WAVES (1. VERTICALLY POLARISED 2. HORIZONTALLY POLARISED) ERROR IN BEARING = C.

FIG. 15.

In connection with these coastal errors it is worthy of note that, with the accumalation of experience of the use of direction-finders on board ship, it is now becoming customary to mark out on charts the « arcs of good bearings » of various transmitting stations, within which the results of observations are found to be reliable (71). Similar arcs can, of course, be provided for shore direction-finding stations or rotating beacons; and their boundaries would be found in the initial calibration of the station for the permanent local errors.

C) *Night Errors and Their Elimination.* — As the result of the analysis of a large quantity of data obtained with wireless direction-finders it can be stated that the minimum distance at which night variations have been consistently experienced is about 30 miles for overland working, observations taken at closer ranges than this showing a maximum error of only 2 deg. or 3 deg. Mesny (58) has stated that night variations may occur for ranges of transmission as small as 15 miles, but according to the author's experience night errors are small at such distances. For example, observations of the bearings of the London broadcasting station taken at Slough, 18 miles away, have shown a maximum error of less than 5 deg. during many months (see Table IV). Similarly, the bearings of the Air Ministry in London, at Teddington, distance 17 miles have shown a maximum error of 4.5 deg. while 99 per cent of the readings were within 2 deg. of the mean bearing. On the other hand, Ongar, which is 30 miles away, gave an error up to 8 deg. at the same observing station, and only 14 per cent of the readings differed from the mean by less than 2 deg. When, however, the path of transmission is entirely oversea, as was the case in the observations carried out at Orford on the transmissions from various ships, the above minimum distance is increased to about 80 or 90 miles (65). This fact is of great importance in the application of direction-finding to marine navigation, and it is perhaps fortunate that the usual conditions connected therewith are that the observed bearings should be accurate at distances which are usually less than 50 miles and never greater than 100 miles. It is now known that under such conditions direction-finding is sufficiently accurate for navigational purposes.

The explanation of the greater range freedom from directional errors due to the diminished attenuation of the direct wave traveling oversea was first given by Wright (73) in 1920. An exactly similar result has been obtained from the experiments carried out at sea in the observation of bearings from a rotating beacon (44).

Even in the presence of night errors their effect can be largely mitigated with either system of direction-finding by taking a series of observations in succession over a period of a few minutes, when the mean bearing so obtained will be much more accurate than a single reading.

As already mentioned in a previous section it is now well known that the night errors experienced in the use of closed-coil direction-finders are due to the action of the horizontally polarized component of the downcoming waves. The effect of the horizontal component of the electric force in producing an error in observed bearing is illustrated by the series of diagrams forming figure 15. It is generally assumed that the downcoming waves have travelled through the upper regions of the earth's atmosphere without deviating laterally from the great-circle plane through the transmitter and receiver. The author believes he is correct in stating that this assumption remains undisputed at the present time, except for wavelengths below about 50 meters. It will be evident, therefore, that any receiving system which is unaffected by a horizontal component of electric force would be free from night errors, even though the vertically polarized downcoming waves might still produce variations in received signal strength. A direction-finding receiving arrangement which fulfils this condition was patented by Adcock (14) in 1919, but this system does not appear to have received practical consideration until Mr. Barfield and the author (74) experimented with it in 1926.

The simplest form of the Adcock aerial system is a pair of spaced vertical aerials arranged to rotate about a central vertical axis, as shown in figure 16, thus forming the equivalent of the single closed-coil direction-finder. By making all connections to the centers of the aerials the horizontal members of the system are compensated so that no e. m. f is induced in the system by a horizontal electric force. To obtain increased sensitivity larger aerials set at a greater spacing may be employed, and when the system becomes too large to rotate, two pairs of such aerials may be employed with closed loops in the Bellini-Tosi direction-finder. The schematic arrangement of such a system is shown in figure 17, while the photograph in figure 18 gives a view of the practical arrangement employed in a series of experiments which have been described in detail elsewhere (74). The type of result obtained is illustrated by the curves given in figure 19, which shows the results of simultaneous observations made on an ordinary closed-coil direction-finder and on one of the Adcock type on the transmissions from a British broadcasting station. It will be seen from this diagram that while the closed-coil set during this period of observations was giving very bad night variations, the corresponding errors observed on the Adcock direction-finder were negligible. It is to be concluded from these and similar results obtained on the transmissions from other broadcasting stations that lateral deviation plays a negligible part in producing the large and va-

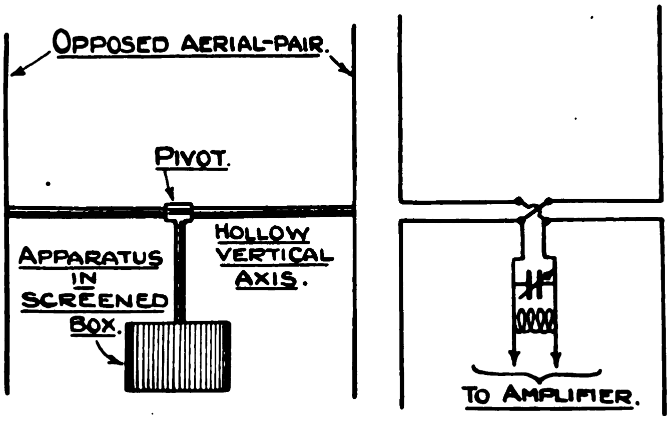

FIG. 16.

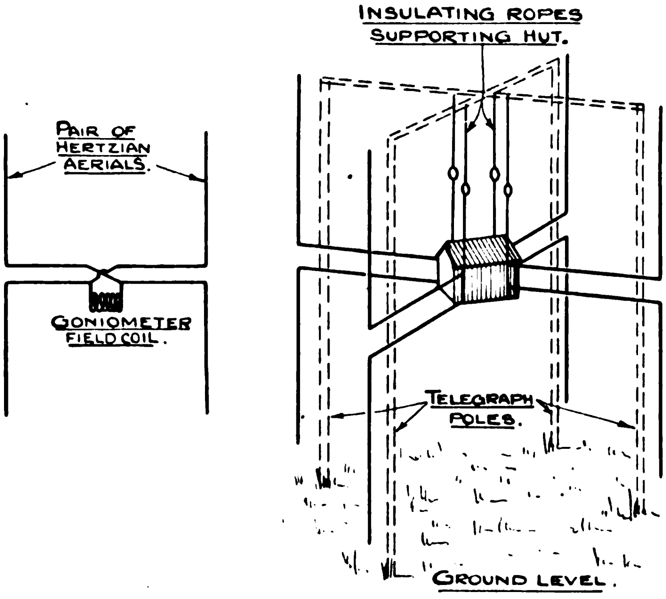

FIG. 17.

riable errors which are obtained at night on the present type of closed-coil direction-finding set, and that therefore these errors are almost entirely caused by the arrival of downcoming waves polarized with the electric force horizontal.

It will be appreciated that it follows from the above conclusions that such a system may be used as a direction-finder which gives the true great-circle plane of arrival of wireless waves, whatever may be their state of polarization or their angle of incidence at the earth's surface. The system should, therefore, have important applications as an accurate direction-finder under night conditions, or for use in observing on transmissions from closed loop type of instrument is subject to large errors. Conversely the Adcock aerial system may be used in place of the closed loop at a directional transmitting station for use either as a course-setter or as a bearing indicator, with freedom from the night errors which have already been experienced (33, 44). The practical development of the system both as a transmitter and as a receiver towards the above ends is now being pursued in Great Britain.

6. Relative Advantages of Direction-Finding by Transmission and Reception for Navigation Purposes.

A) *Location of the Direction-Finder.* — At the outset it must be admitted frankly that, owing to the more advanced state of its development at the present time, the wireless direction-finder when used in a fixed position on land gives a somewhat superior accuracy to the rotating beacon; for it is not easy to obtain bearings on the rotating beacon to a greater accuracy than two degrees, whereas a good land direction-finding station should give bearings reliable to one degree. This, however, is not the whole story and reference must be made to the conclusions of a controversy of long standing on the matters of the location of the direction-finder, whether on ship or shore, and of the individual upon whom it is most desirable to place the responsibility of observing the bearings. Without giving the full details of this controversy it may be stated that it is very desirable for the navigator to take the wireless bearings personally or have these observations made by somebody under his direct control and supervision. Since the navigator is responsible for the safety of his ship it is unreasonable to expect him to rely, particularly in emergencies, upon observations made at a shore direction-finding station by a man quite unknown to him, and of whose skill and reliability he is quite unable to judge. In addition there is the possibility of error in signalling the bearings from shore to the ship, the interference to other wireless traffic in doing so, and the point of some strategic importance that the information as to the ship's bearings or position is broadcast to all wireless stations in the vicinity.

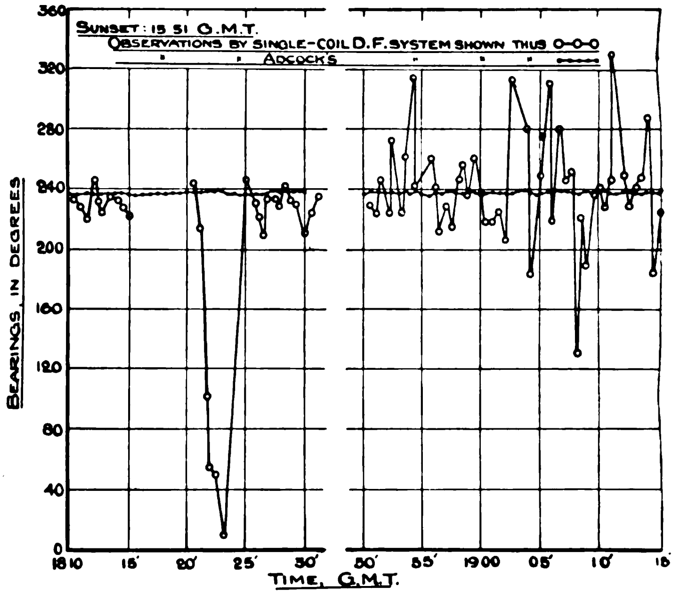

FIG. 19.

Observations of Bearings on Bournemouth, December 10, 1925 ($\lambda = 386$ m).

It will be evident, therefore, that the most desirable position for the wireless direction-finder is on the ship itself, and this view is confirmed by the fact that during the past few years an increasing number of ships have been fitted with direction-finders whereas the number of shore direction-finding stations has never been large and is decreasing. The true comparison to be made, therefore, is between the rotating beacon transmitter set up on shore and the direction-finder installed on board ship. In the following paragraphs the discussion of this compari- which one system appears to have over the other.

B) *Superiority of the Ship Direction-Finder over the Rotating Beacon.* — It was considered at one time that with the installation of the direction-finder on board ship the necessity for special transmissions for wireless bearing purposes would be eliminated. This, however, has been found not to the case and it is now the practice to erect fixed transmitting stations or beacons (75) for the sole purpose of providing special transmissions for the use of ship direction-finding sets. These beacons are usually located near lighthouses or on light-vessels at points of importance for navigation. The use of the direction-finder is not limited to such beacons, for bearings may be taken upon the transmissions from any land station the position of which is accurately known. It has been found, for example, that some broadcasting stations form very useful fixed beacons operating for many hours of the day when it is desired to take wireless bearings on a ship at sea. The navigator with a direction-finder under his control thus has the opportunity of taking a series of cross-check bearings and so of improving the accuracy of determination of his position.

A further advantage of the ship fitted with the direction-finding set is that the opportunity is provided for observing bearings upon the transmissions from other ships. This may be useful when contact is made with a ship which knows its own position, but it is of greater importance when applied to the location of ships in distress, as has already been demonstrated in several practical cases. Moreover, there is the possibility that the future development of the ship direction-finder will provide a means for reducing or avoiding collisions between ships in foggy weather.

These advantages are not possessed by the rotating beacon system which provides the ships with the opportunities of obtaining bearings only during the operation of such beacons, and in those areas of the world in which these beacons are installed. The navigator with a direction-finding set under his immediate control would probably use it very frequently and would thus soon become aware of the occurence of any fault or error. With the rotating beacon system he would be dependent upon information from the shore station staff as to any such errors; but against this it may be urged that such a staff would be more expert at dealing with and removing the error than would the average navigator or wireless operator.

C) *Superiority of the Rotating Beacon over the Ship Direction-Finder.* — By way of countering the remarks made in the above section it may be said that the rotating beacon transmitter retains all the advantages which were sacrificed when the direction-finding installation was moved from the shore to the ship. These advantages comprise the fact that the directional part of the system is fixed in position on solid ground and that it can, therefore, be accurately oriented and calibrated at installation, and also that it can be under the continuous supervision of experts. One directional shore station will provide service to an almost unlimited number of ships, whereas each ship direction-finder must be carefully installed and operated by experienced men.

One of the great advantages of the rotating beacon system is that no apparatus beyond a simple wireless receiver and a chronograph is necessary on the ship itself; a direction-finding service is thus provided for ships of all classes from the largest to the smallest. In the case of many small ships it would not be practicable to install a direction-finder with any pretence to accuracy; and to the large ship already fitted with a direction-finding set a rotating beacon would be an additional asset in enabling further bearings to be taken either for check purposes or for position determination. Furthermore, the method of observing bearings is so simple that they can easily be determined by the navigator himself in any portion of the ship without necessarily requiring the assistance of a wireless operator.

It has already been hinted that the accuracy of bearing observation by direction-finder on a ship at sea is less than that obtainable with a similar installation on land. The difference is, in fact, sufficient to make the optimum accuracy of ship direction-finder comparable with that of the rotating beacon system. The direction-finding bearing is taken relative to the direction of the ship's head, and its accuracy depends upon the steadiness of the ship and also upon the accuracy with which the direction of the ship's head is given by the compass reading at any desired instant. In anything but a calm sea it is difficult to keep the head of a small ship steady to within one or two degrees, and in a rough sea the swing may amount to five degrees or more. Also there is probably a lag between the actual direction of the ship's head and the reading of the compass, whereas no such lag exists on the direction-finder. The bearing obtained from the rotating beacon is entirely free from these limitations and its accuracy is practically the same whether the ship is at sea or in dock. Also since the accuracy of observed bearing has been shown to be largely immune from conditions local to the receiver, no correction or compensation is necessary corresponding to the quadrantal error associated with the ship direction-finder. This error is likely to be serious in the case of many small ships, and there is the added possibility of its alteration with draught and nature of cargo.

The limitation of range of accurate bearings due to night effect has been shown, both theoretically and experimentally, to affect both systems of directional wireless to the same degree. The accuracy of the rotating beacon has also been found to be sensibly the same for both continuous wave transmission and interrupted continuous wave transmission . Considering the possibility of interference of the rotating beacon transmitters with other wireless services, a similar objection may be raised to the fixed beacon transmitter which has been found to be so necessary in conjunction with the ship direction-finder. In neither case, however, is any serious interference likely to be caused since definite and distinct wavelengths have now been allocated to both types of beacon.

A small point just worthy of mention in concluding this section is that rotating beacons erected on the coast would be of some considerable service to aircraft navigators, particularly those making daily flights along the principal air routes.

D) *Conclusions.* — It will be gathered from the above discussion that the rotating beacon system is considered to have some advantages over the ship's direction-finder in the application of directional wireless to marine navigation. These advantages are, however, probably not sufficiently well defined at present as to make the future policy of those concerned with these matters independent of certain other factors; and in any case it is evident that the economics of the situation must be considered as well as the technical features. The rotating beacon system would at first appear to be an economy in that the whole cost of the directional apparatus is removed to the authority controlling the shore stations; and it is to be presumed that the cost of installing and maintaining the rotating beacons would be met by the levy of a tax upon all ships using the beacons. This might be a great advantage to the shipowners who, judging from their tardiness in equipping their ships with direction-finders, do not appear to find this apparatus very cheap. To the cost of such direction-finders, moreover, is to be added that of the fixed beacons specially built for their use. This cost depends upon local conditions and whether or not the beacon can be installed at an existing lighthouse and maintained by the personnel of the lighthouse. The first rotating beacon for practical working to ships has yet to be built so that details of the cost are at present unknown.

7. Acknowledgments.

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LE PROBLEME DE L'ONDE UNIQUE EN TELEPHONIE SANS FIL,

par R. MOENS et M. COSYNS.

La multiplicité croissante des postes d'émissions radio-électriques a posé le problème de la répartition de leurs longueurs d'ondes. Les valeurs de celles-ci ne pouvant pratiquement dépasser 3 kilomètres, le nombre de postes de radiophonie que l'on peut admettre sans brouillages réciproques est assez restreint. On admet que la différence de leurs fréquences ne peut descendre au-dessous de 5,000 vibrations/seconde, la bande des fréquences musicales s'étendant entre 10 et 5,000 au moins, et cette convention est nettement insuffisante quand on tient compte de ce que la plupart des postes européens transmettent outre l'onde porteuse les deux sidebands et que, circonstance plus grave, peu de postes ont leur longueur d'onde stabilisée.

Ainsi s'est posé le problème de l'onde unique qui consiste à établir plusieurs postes sur des λ identiques et ne pouvant donner d'interférences entre les ondes porteuses. La difficulté consiste en ce que cette égalité de fréquence doit être réalisée à moins de 10 à 15 vibrations/seconde près, faute de quoi les ondes porteuses donnent une interférence audible, ce qui amène un brouillage complet entre ces deux postes.

Le problème de l'onde unique comporte deux parties :

1° Établir deux ou plusieurs postes ayant des λ stables à quelques vibrations/seconde près. Ce problème est résolu actuellement d'une façon simple et pratique par le quartz piézo-électrique.

2° S'arranger pour que ces deux fréquences soient égales à moins de 10 vibrations/seconde près.

On a espéré pouvoir arriver à cette fin en taillant deux quartz exactement sur la même λ. Cela est pratiquement irréalisable. L'épaisseur de 1 mm. de quartz correspond à 3 millions de cycles/seconde environ, et il faudrait donc réaliser cette égalité d'épaisseur à moins de 10 à 15 millionièmes de millimètre. On a proposé alors (Meissner) de corriger un peu la fréquence propre du quartz, en mettant une petite capacité en série sur lui. Mais cette solution diminue considérablement l'énergie et la stabilité des oscillations piézo-électriques.

Nous avons résolu le problème de la façon suivante :

Nous établissons un poste A stabilisé par quartz sur une fréquence F_1 et nous nous proposons à partir d'un quartz de fréquence F_2 voisin de F_1 $[|F_1 - F_1| = f]$ de construire une onde stabilisée et égale à F, à moins de 10 à 15 cycles. Cela revient donc à obtenir une oscillation de fréquence F_1, à partir d'une fréquence F_2 et d'une fréquence f, ou encore au problème plus général d'ajouter deux fréquences de pulsation ω et Ω.

Un calcul approché mais simple montre la possibilité de ce problème au moyen de deux triodes que nous supposerons identiques (même résistance filament-plaque ρ et même facteur d'amplification k) (fig. 2). Désignons-les par L_1 et L_2 et par i_1 et i_2 les courants de plaques (ou plutôt les variations de ceux-ci autour d'une valeur moyenne).

Introduisons dans la grille de la première lampe L_1 à la fois une force électromotrice de la forme $a \sin \omega t$ et $b \sin \Omega t$. Faute de mieux, on décompose les caractéristiques des lampes à trois électrodes en plusieurs régions : une région à courbures positives pour les voltages grille faible, une région quasi rectiligne, une région à courbure négative finissant dans la région horizontale de saturation.

Nous aurons, en arrêtant le développement en série de la fonction $i = f\,(a \sin \omega t + b \sin \Omega t)$ au 3° terme,

$$\frac{\rho}{k} i_1 = (a \sin \omega t + b \sin \Omega t) + \alpha\,(a \sin \omega t + b \sin \Omega t)^2$$
$$+ \beta\,(a \sin \omega t + b \sin \Omega t)^3.$$

Introduisons également cette même *f. e.* (a sin $\omega t + b$ sin Ωt) dans le circuit de grille de la 2^e^ lampe L_2, mais en ayant soin d'inverser la phase de l'oscillation Ωt. Nous aurons, en faisant la même hypothèse simplificatrice (sin Ωt est à remplacer par — sin Ωt),

$$\frac{\rho}{k} \cdot i^2 = (\alpha \sin \omega t - b \sin \Omega t) + \alpha (a \sin \omega t - \rho \sin \Omega t)^2 + \beta (a \sin \omega t - b \sin \Omega t)^3.$$

Induisons ces variations i_1 et i_2 respectivement dans les deux selfs l'_1, l'_2 couplées aux deux selfs l_1, l_2 placées dans les circuits de plaques de L_1 et L_2.

Nous aurons ainsi dans celles-ci des *f. e.* induites proportionnelles à

$$\begin{aligned} v_1 = {} & (a\omega \cos \omega t + b\Omega \cos \Omega t) \\ & + 2\alpha (a \sin \omega t + b \sin \Omega t) (a\omega \cos \omega t + b\Omega \cos \Omega t) \\ & + 3\beta (a \sin \omega t + b \sin \Omega t)^2 (a\omega \cos \omega t + b\Omega \cos \Omega t), \end{aligned}$$

ou

$$\begin{aligned} v_1 = {} & (a\omega \cos \omega t + b\Omega \cos \Omega t) \\ & + 2\alpha \begin{bmatrix} a^2\omega \sin \omega t \cos \omega t + ab\omega \sin \Omega t \cos \omega t \\ + ab\Omega \sin \omega t \cos \Omega t + b^2\Omega \sin \Omega t \cos \Omega t \end{bmatrix} \\ & + 3\beta (a^2 \sin^2 \omega t + 2ab \sin \omega t \sin \Omega t + b^2 \sin^2 \Omega t) \\ & \qquad (a\omega \cos \omega t + b\Omega \cos \Omega t) \end{aligned}$$

et

$$\begin{aligned} v^2 = {} & (a\omega \cos \omega t - b\Omega \cos \Omega t) \\ & + 2\alpha \begin{bmatrix} a^2\omega \sin \omega t \cos \omega t - ab\omega \sin \Omega t \cos \Omega t \\ - ab\Omega \sin \omega t \cos \Omega t + b^2\Omega \sin \Omega t \cos \Omega t \end{bmatrix} \\ & + 3\beta (a^2 \sin^2 \omega t + 2ab \sin \omega t \sin \omega t + b^2 \sin^2 \Omega t) \\ & \qquad (a\omega \cos \omega t - \rho\Omega \cos \Omega t). \end{aligned}$$

En reliant l'_1 et l'_2 en série, mais de façon à avoir ces *f. e.* en opposition de phases, nous aurons finalement dans ce circuit un *f. e.*:

$$\begin{aligned} v_1 - v_2 = {} & 2b\Omega \cos \Omega t + 2\alpha \begin{bmatrix} 2ab\omega \cos \omega t \sin \Omega t \\ + 2ab\Omega \sin \omega t \cos \Omega t \end{bmatrix} \\ & + 3\beta \, . \, 4ab \sin \omega t \sin \Omega t \, . \, a\omega \cos \omega t \\ & + 3\beta (2a^2 \sin^2 \omega t + 2b^2 \sin^2 \Omega t) \, b\Omega \cos \Omega t, \\ = {} & 2b\Omega \cos \Omega t + 2\alpha ab \left\{ \begin{matrix} \omega \begin{bmatrix} \sin (\omega t + \Omega t) \, t \\ - \sin (\omega t - \Omega t) \, t \end{bmatrix} \\ + \Omega \begin{bmatrix} \sin (\omega t + \Omega t) \, t \\ + \sin (\omega t + \Omega t) \, t \end{bmatrix} \end{matrix} \right\} \\ & + 3\beta a\omega \cos \omega t \, . \, 2ab \, . \begin{bmatrix} \cos (\omega - \Omega t) \, t \\ - \cos (\omega + \Omega t) \, t \end{bmatrix} \\ & + 3\beta b\Omega \cos \omega t \begin{bmatrix} a^2 (1 - \cos^2 \omega t \\ + b^2 (1 - \cos^2 \Omega t \end{bmatrix}, \\ = {} & 2b\Omega \cos \Omega t + 2\alpha ab \begin{bmatrix} (\omega + \Omega) \sin (\omega + \Omega) \, t \\ - (\omega - \Omega) \sin (\omega - \Omega) \, t \end{bmatrix} \\ & + \beta \times A. \end{aligned}$$

Nous négligeons les deux derniers termes : **ils** ont des coefficients constants ($a^2 b\omega$ et $a^2 b\Omega$) **du** même ordre de grandeur que les premiers, **mais** le facteur commun β est beaucoup plus petit **que** le facteur α des autres termes. On peut donc **les** négliger, et l'on constate alors que cette *f. e.* contient deux composantes d'amplitude sensiblement égale ($\omega + \Omega$ et $\omega - \Omega$), mais de pulsation $\omega - \Omega$ et $\omega + \Omega$.

On dispose donc, en isolant au moyen de filtres passe-bas ou passe-haut, soit l'oscillation de pulsation $\omega + \Omega$, soit celle de pulsation $\omega - \Omega$, d'une nouvelle oscillation ayant la fréquence cherchée correspondant à la pulsation $\omega + \Omega$ ou $\Omega - \omega$.

La composante en ωt s'élimine d'elle-même, étant fort différente des autres (fréquence bien plus basse).

Nous avons fait l'essai expérimental sous la forme suivante (fig. 3) :

L'oscillation ω (celle qui sera stabilisée par quartz) était donnée par un petit oscillateur à lampe O_ω (20 watts Fotos) dont la longueur d'onde était variable pour l'essai et était de quelques centaines de mètres.

L'oscillation Ω provenait d'un autre oscillateur O_Ω de fréquence plus basse (quelques dizaines de kilomètres) et également variable.

L'oscillateur O_ω couplé au moyen de 2 selfs avec les selfs l''_1, l''_2, introduit ainsi dans les circuits-grille des lampes L_1 et L_2 les *f. e.* $+ a$ sin ωt et $+ a$ sin ωt en question.

Ces circuits de grille comportent également deux résistances non inductives R_1 et R_2 traversées par un courant réglable (par des capacités non indiquées) fourni par O_Ω. Le sens de connexion avec celui-ci est tel que les tensions en R_1 et R_2 soient en opposition de phases (b sin Ωt et — b sin Ωt). Ces résistances sont d'ailleurs shuntées par de petites capacités C_1 et C_2 servant de ponts pour l'oscillation de haute fréquence ω.

Sh_1, Sh_2 et C'_1, C'_2 sont les selfs de choc et les condensateurs de passage des circuits amenant la haute tension, commune aux deux lampes. Le circuit de chauffage et la batterie de chauffage des filaments, également commune aux deux lampes, ne sont pas représentés.

l_1, l_2 sont les selfs parcourues par le courant de plaques i_1, i_2 et l'''_1, l'''_2 sont des selfs couplées à celles-ci de façon qu'elles deviennent le siège de *f. e.* induites en opposition de phases (v_1 et v_2).

Réunies en série de cette façon, elles sont le siège des *f. e.* $v_1 - v_2$ calculées plus haut et comportant les composantes en $\omega + \Omega$ et $\omega - \Omega$.

L'expérience nous a montré qu'on peut facilement et très nettement isoler l'une des oscillations cherchées, par exemple $\omega + \Omega$ en procédant de la façon suivante :

On accorde d'abord le circuit l_1, l_2 sur cette fréquence au moyen d'un condensateur Γ relié aux deux extrémités côté plaque de ces selfs.

De même on accorde le circuit l'''_1, l'''_2 au moyen du condensateur Γ'.

L'essai a été fait avec deux lampes Fotos 20 watts, chauffage normal, tension plaque 440 volts.

La théorie fait prévoir qu'il y a avantage à négativer les deux lampes. De cette façon, en effet, le point de fonctionnement reste entièrement dans la région à courbures accentuées

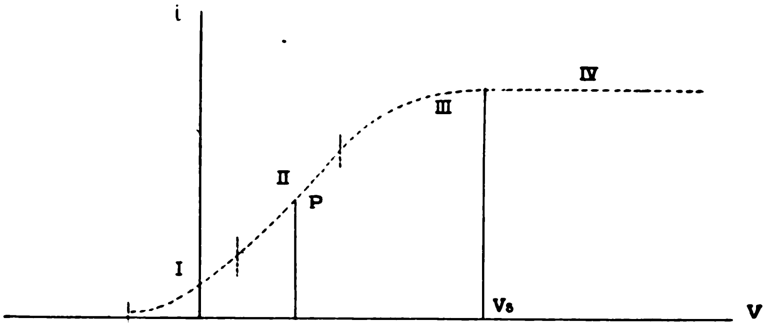

FIG. 1.

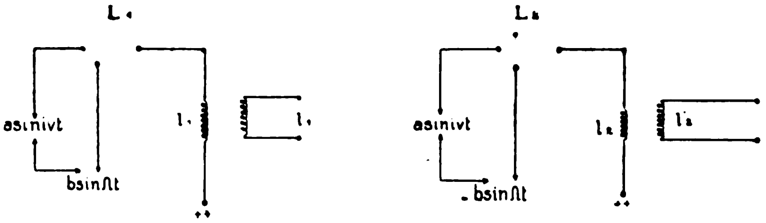

FIG. 2.

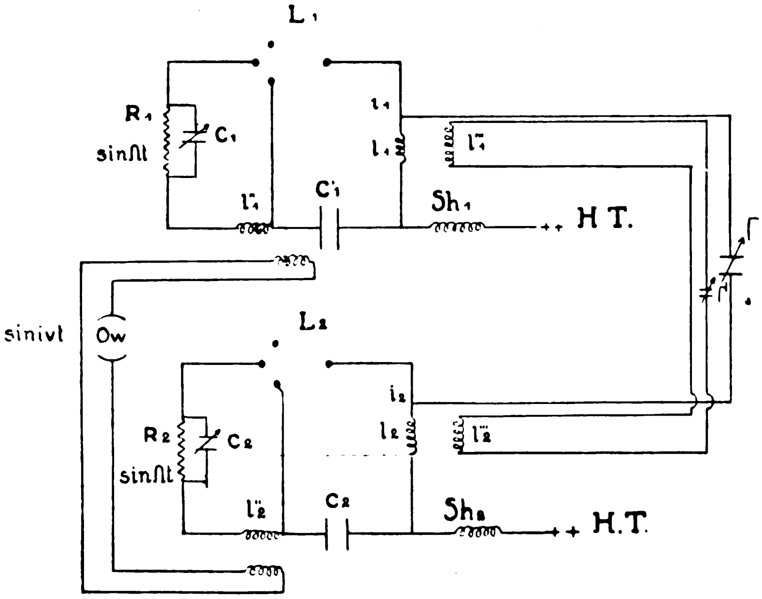

FIG. 3.

(région I, fig. 1), ce qui accentue le coefficient *a* de nos calculs et, par suite, l'amplitude des composantes $\omega + \Omega$ et $\omega - \Omega$.

C'est ce que l'expérience a entièrement confirmé. Il y a avantage à négativer de telle façon que les courants de plaque, sans les *f. e.* induites, se réduisent presque à zéro.

De même il y a avantage de s'arranger pour que les *f. e.* induites de pulsations ω et Ω soient égales en amplitude.

Dans ces conditions, et en achevant l'accord comme il a été expliqué plus haut sur l'onde cherchée (ω et Ω), on obtient celle-ci avec une puissance comparable à celles utilisées pour ω et Ω.

A titre d'indication, nous avons fait ce réglage en absorbant cette énergie dans une petite ampoule à incandescence qui brillait normalement pour un couplage assez lâche, à peu près comme c'est le cas pour ces lampes utilisées en oscillation simple.

Voici donc comment on opérera si l'on veut construire deux ou plusieurs postes A, B, ... travaillant sur « onde unique ».

L'un des postes, A par exemple, sera un poste normal stabilisé par quartz. Supposons, pour fixer les idées, $\lambda = 300$ m., $F = 10^6$.

En B, on construira, d'une part, un oscillateur O_ω stabilisé également par quartz sur une λ voisine à 1 % par exemple de celle de A, et, d'autre part, un oscillateur O_Ω de fréquence égale à celle de A moins celle de O_ω (dans ce cas $f = 1\ \%$ de $10^6 = 10.000_\omega$), et l'on appliquera le montage et le procédé indiqués plus haut. On amplifiera cette puissance jusqu'à la valeur désirée. Nous aurons en B le poste demandé.

En effet, l'oscillation de O_Ω étant dans le domaine des fréquences basses, on obtiendra facilement que cette fréquence reste constante à quelques cycles-seconde près (chauffage des filaments bien constant, haute tension bien stable, ...). Les autres fréquences, celle de A et celle de O_ω (oscillateurs stabilisés au quartz), resteront également constantes à 10 ou 15 cycles près.

On aura donc une égalité permanente entre les longueurs d'ondes de ces postes à moins de 10 ou 15 cycles près, ce qui est suffisant pour éviter tout brouillage entre les deux postes.

En ce qui concerne la stabilité des λ obtenue par les quartz piézo-électriques, elle est remarquable.

A ce sujet, il n'est peut-être pas sans intérêt de signaler le résultat d'un de nos essais. Disposant de deux quartz dont les fréquences propres (environ 2.10^6) sont très voisines, nous avons monté des oscillateurs à lampe (deux lampes 20 Watts Fotos) stabilisés chacun par ces quartz et avons observé le son d'interférence obtenu après détection (son 2,000 environ). Pendant toute la durée de l'expérience et quelles que soient les variations produites par ailleurs (variation de la température du filament, capacité de la main ...), nous n'avons pas obtenu de changement notable (tout au plus 1 ton) dans la hauteur du son du battement. Sans aucune précaution, et à condition de ne pas faire varier la température d'un des quartz, on obtient un son remarquablement stable; surtout quand on songe à l'influence considérable des petites variations de capacité, de chauffage, etc... sur la longueur d'onde dans le domaine de ces hautes fréquences.

Nous croyons devoir signaler, en terminant, que l'idée de cette solution nous est venue à la lecture d'un tiré à part des « Bell Telephone Laboratories » (communiqué de Schilleng et Oswald).

Ce travail a été effectué au laboratoire
de M. le Prof^{r} Verschaffelt, à l'Université de Gand.

NOTE AU SUJET DE CERTAINS DISPOSITIFS UTILISES POUR L'ETUDE DE LA PROPAGATION DES ONDES RADIO-ELECTRIQUES

par le Général FERRIÉ.

Dans ces dernières années, de curieux phénomènes de réflexions multiples ont été mis en évidence dans la propagation des ondes radioélectriques. J'ai fait entreprendre par mes services une étude systématique à ce sujet. Cette étude est loin d'être achevée et les résultats complets n'en pourront être publiés que plus tard. Cependant ils permettent déjà de confirmer ceux qu'ont obtenus les autres expérimentateurs, car à 20 kilomètres du poste de la Tour Eiffel transmettant sur 75 mètres de longueur d'onde, on a mis en évidence des échos arrivant au poste récepteur avec des retards atteignant parfois le centième de seconde.

Mais au cours de ces recherches, mes collaborateurs ont été amenés à réaliser certains dispositifs expérimentaux qui semblent intéressants et dont la connaissance peut être utile à ceux qui s'occupent de recherches relatives à la propagation des ondes.

Tout d'abord, pour mettre en évidence les différentes réflexions qui peuvent se produire sur les hautes couches de l'atmosphère, il est nécessaire de produire des émissions aussi brèves que possible.

Voici le montage réalisé au poste de la Tour Eiffel par M. Bonnemaire, ingénieur au Centre Radiotélégraphique de Paris. Un tube à néon N est alimenté par une batterie E de 200 volts environ à travers une résistance R de 4 Ω et une inductance L de quelques henrys. Une capacité C règlable, disposée aux bornes du tube, détermine la constante de temps du système. Les oscillations de relaxation engendrées produisent des variations de courant très brusques qui fournissent au secondaire du transformateur T des pointes de tension très brèves. Ce transformateur attaque le dispositif de modulation d'un poste émetteur radiotélégraphique. En choisissant convenablement E, L et C, on obtient, toutes les secondes environ, un top extrêmement sec.

Le meilleur moyen de mettre en évidence l'existence de réflexions multiples et d'échos est évidemment de disposer au poste récepteur d'un galvanomètre à indications rapides muni d'un enregistrement photographique. Mais ce procédé est assez dispendieux et d'un emploi assez long, car il ne permet d'être fixé sur l'existence des échos qu'après développement des pellicules. Il se prête donc mal à une étude continue des phénomènes.

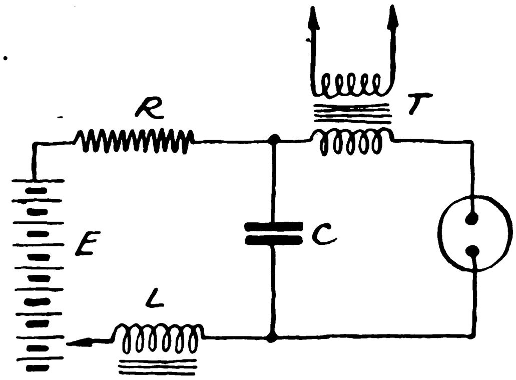

FIG. 1.

MM. Jouaust et Decaux ont cherché à lui substituer un procédé basé sur les propriétés de l'audition binauriculaire que nous avions adaptée pendant la guerre à l'écoute des bruits souterrains et aériens :

Un transformateur basse fréquence à deux secondaires S_1 et S_2 est branché à la sortie de l'amplificateur de réception. Chacun des secondaires attaque la grille d'un triode (T_1 et T_2). Le circuit de plaque de chaque triode se ferme par un écouteur (E_1 et E_2) et par une source de courant alternatif A à fréquence musicale réglable (en pratique un petit oscillateur à lampe). Les deux circuits de plaque sont branchés en sens inverse sur la source. Les deux plaques sont donc alimentées en opposition de phase; lorsque l'une est positive, l'autre est négative, de sorte que les écouteurs sont en service l'un après l'autre alternativement. L'appareil fonctionne en somme comme un inverseur périodique. Supposons deux signaux très brefs se succédant avec un intervalle de temps égal à la moitié de la période de la source A. Si, lorsque le premier signal arrive, la plaque de T_1 est positive, l'écouteur E_1 seul rendra un son; lorsque le second signal arrivera, ce sera la plaque de T_2 qui sera positive et l'écouteur E_2 seul fonctionnera. L'opérateur ayant un écouteur sur chaque oreille aura l'impression d'entendre un seul top à la fois dans les deux oreilles. Au contraire, un top unique ne serait entendu que par une oreille. Ce phénomène est net et sensible; en variant la fréquence de la source, on sent très bien le moment où les périodes de la source et des tops deviennent égales. De plus si la durée d'un signal unique dépassait celle d'une alternance, on aurait également l'impression de l'audition dans les deux oreilles. On possède donc une méthode permettant d'évaluer simplement une limite supérieure pour : 1° l'intervalle de temps séparant deux signaux brefs; 2° la durée d'un signal.

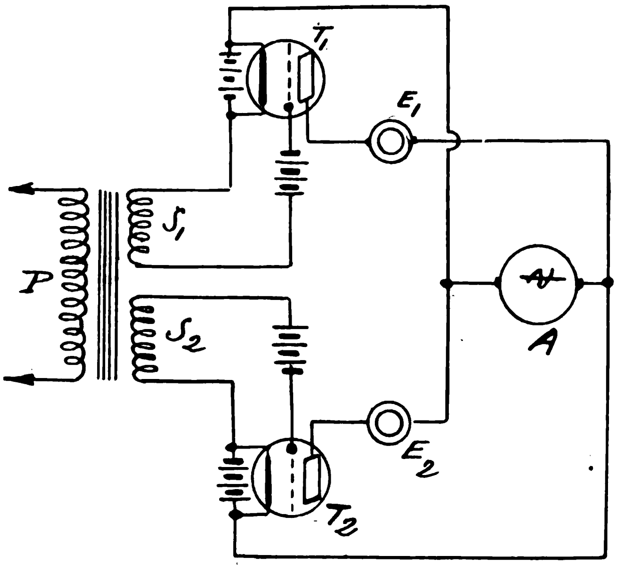

FIG. 2.

Appliquant cette méthode à la détermination des échos, on voit qu'en faisant varier la fréquence de la source locale il est possible d'apprécier le temps qui s'écoule entre l'arrivée de l'onde directe et de l'onde réfléchie.

Ce dispositif employé à très courte distance au poste de la Tour Eiffel a permis, d'autre part, d'apprécier la durée des émissions brèves produites par le premier dispositif signalé plus haut, et de constater que cette durée était inférieure au 1/10.000^e de seconde.

Ce dispositif permettrait donc l'étude simultanée des phénomènes d'écho par de nombreux expérimentateurs, le matériel mis en œuvre étant absolument courant, facile à monter et très simple à manipuler. Bien que les résultats obtenus soient forcément moins précis et moins complets qu'avec un enregistrement, la multiplicité des observations fournirait probablement des indications précieuses sur l'allure des phénomènes.

3 septembre 1928.

EXPERIMENTS IN RECORDING RADIO SIGNAL INTENSITY.

by L. W. AUSTIN.

Laboratory for Special Radio Transmission Research - Bureau of Standards.

It was originally thought that daylight observations represented normal radio transmission, while night observations showed the normal transmission disturbed by reflection effects the study of which might be properly neglected until the simpler daylight conditions were better understood. In recent years, however, it has become increasingly evident that daylight and night transmission phenomena are so interconnected that there can be no clear understanding of the first without considering the second. Therefore, as our laboratory personnel was too limited to permit night watches, it was decided to try automatic recording. Our apparatus has been described by my assistant, Mr. Judson, in another place (*). It consisted briefly of an autodyne

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(*) *Proc. I. R. E.*, vol. XVI, p. 666, 1928.

detector such as we have long used for daylight measurements by the telephone comparator method (*) and several stages of audio frequency amplification. The last audio frequency stage is coupled inductively to a tube rectifier circuit containing the Cambridge recorder, wich prints the deflections on a revolving drum every half minute. By means of a clock relay, described in Mr. Judson's article, different stations can be tuned in or the circuit can be connected to different signal collector systems as may be necessary for the different records desired.

Automatic recording has some bad as well as good features. While it gives easily a vast number of series of observations, it is somewhat limited in its accuracy and dependability as compared with the work of personal observers. For example, unknown disturbances may at times intrude themselves and not be detected, and accidents may happen to the apparatus rendering a whole night's work useless.

Until the time comes when special transmitting stations are operated purely for experimental purposes, continuous records, continued day after day for months at a time, can evidently be made only on regular traffic from commercial transmitting stations. This, of course, rules out all extended experiments depending on special signals. Commercial stations are more or less irregular, seldom sending much on Saturday nights or on Sundays, and sometimes closing down entirely for considerable periods.

The particular system of recording which we have adopted has certain good points which deserve mention. By using only audio-frequency amplification a very good degree of constancy of calibration can be obtained over periods of many months. If the filament currents of the amplifier are kept constant within ±1.5 per cent and the plate voltages with about ± 10 per cent, the changes in sensitivity will not be greater than ± 10 per cent which is about the limit of accuracy in measuring absolute signal intensity from commercial sending.

Another convenient fact is found to be that it is quite possible with this type of recorder to get a nearly linear relationship between the antenna voltage and the recorder deflection over most of the scale.

It is also found that when interference, either from atmospherics or from stations, is less in intensity than the signal being measured, the two effects do not superpose on the recorder, *i.e.*, the rectifier responds only to the stronger of two signals. It is only when the two signals or disturbances are nearly equal, that is, differing less than about 15 %, that a certain amount of superposition occurs.

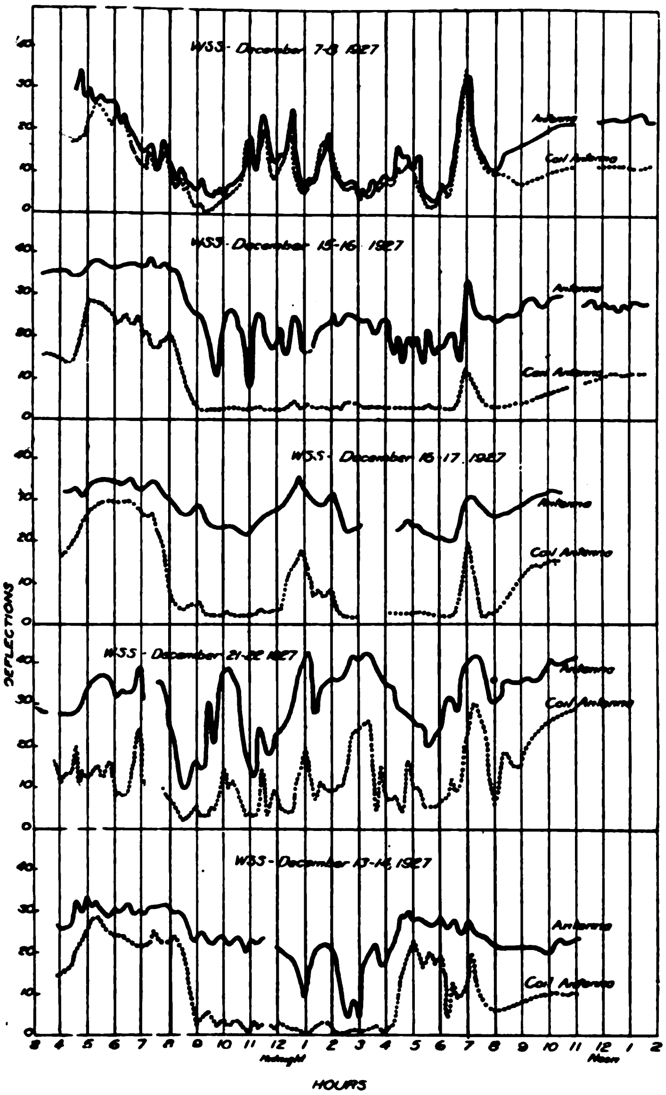

FIG. 1.

Some of the work which is being done by means of automatic recording is described below.

Reception Variation. — The recorder was first used for registering the general changes in long wave signal intensity during the day and night.

(*) *Proc. I. R E.*, vol. XXII, p. 521, 1924.

In the beginning an attempt was made to measure a large number of stations, observing each station for five minutes in every hour. Curves of this kind were shown in Mr. Judson's paper already cited. While this method was fairly satisfactory, at least with distant stations, it was soon decided that, on account of the rapid changes in intensity, more frequent observations on each station were desirable. In recording the transoceanic long wave stations, with which our work largely deals, it was found, especially in the cases of stations at distances of less than 1000 km, that the sequences of change in intensity showed very great variability on different nights. The degree of this variability may be seen in the collection of curves in figure 1. In this figure the curves are made up from series of ten recorder points taken each half minute with five minute intervals after each series. In considering the variability of the curves without going into the possible causes of variations, we see at once that curves taken on single nights, or even on a considerable number of nights, would have very little value for purposes of generalization. It was thought at first that there were more or less periodic cycles of night change, the same patterns of change repeating themselves every two or three weeks, but we are now doubtful as to the existence of such cycles, apart from the possible effects of magnetic and solar disturbances.

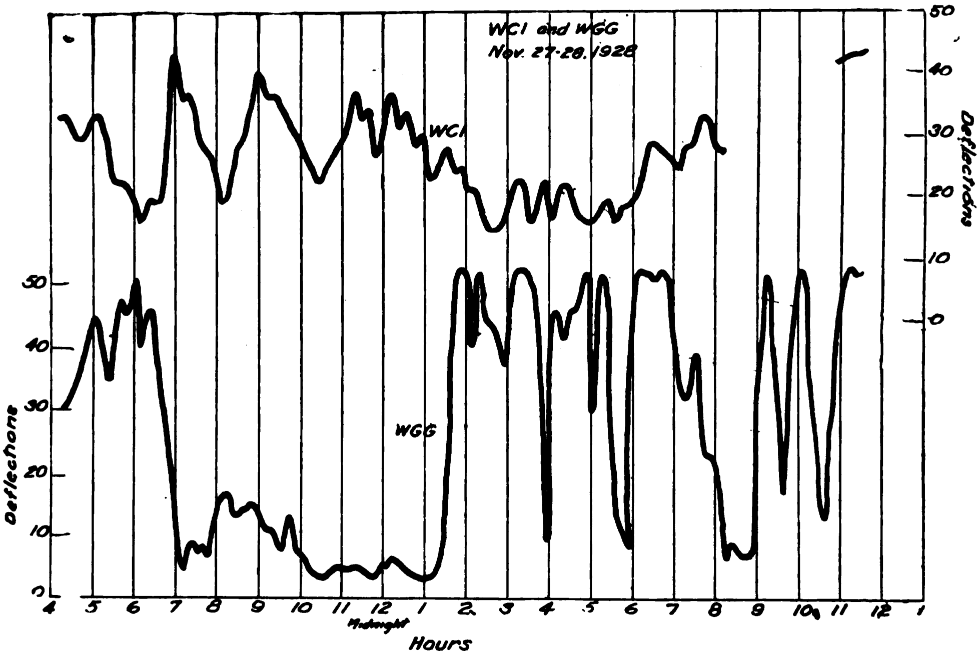

FIG. 2.

Figure 2 shows the differences which may exist in the night changes in signals of somewhat different wave length coming along the same path at the same time. The two stations, WCI ($\lambda = 16350$ m.) and WGG ($\lambda = 13500$ m.), are both at Tuckerton, N. J., 251 km. from Washington, WCI transmitting from an umbrella antenna while WGG makes use of a flat top antenna. It is not believed, however, that the differences observed are produced by the antenna forms as similar differences are also found in other pairs of stations both using flat top antennas.

In the case of transmission over distances short enough to make the ground wave comparable in intensity with the downcoming wave, it must be remembered that the phase relation between the two, *i. e.*, the difference in length of their paths, is probably the chief factor in determining whether the signals intensities at night rise above or fall below their daylight values. This fact must be remembered in making use of the night signals from stations with strong ground waves for the study of the correlation of radio transmission with other natural phenomena.

It is generally believed that below the Kennelly-Heaviside layer there is a region of sufficiently great ionization to produce absorption in the downcoming wave, certainly in the day time and perhaps, in a lesser degree, at night. The relative importance of reflection or refraction in the Kennelly-Heaviside layer, and absorption in the absorbing layer in affecting signal intensity is not yet by any means clear, the absorption probably being more important in the day time, and the changes in reflection at night.

Measurement of Downcoming Wave Angle. — Another use for the automatic recorder is the continuous determination of the angle with the horizontal at which the downcoming wave reaches the receiving station. A method for calculating this from observations made on a vertical antenna and on a loop has been given by Appleton and Barnett (*).

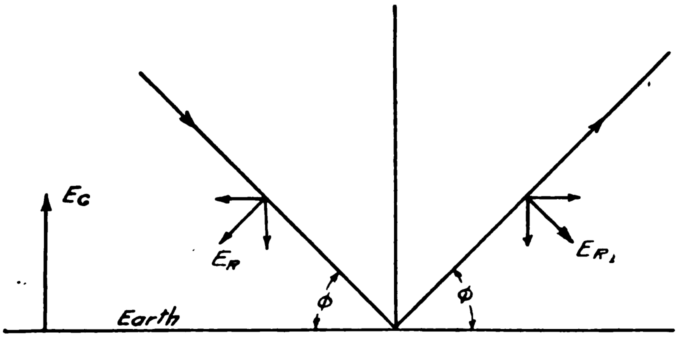

FIG. 3 A.

In the following explanation, for the sake of the clearness of the physical picture, the electric field is considered both in the case of the antenna and of the loop, instead of considering the electric field in the case of the antenna and the magnetic field in the case of the loop, as in the paper by Appleton and Barnett.

Suppose the case of a radio wave passing along the ground with its electric force E_G vertical and a reflected or refracted wave from the same source coming down from the Kennelly-Heaviside layer at an angle Φ with the horizontal and with its electric force E_R at right angles to the direction of propagation and in the propagation plane. E_R on account of the difference in length of the two paths will, in general, be out of phase with E_G.

From figure 3A, it is seen that the downcoming wave E_R before and after reflection from the earth will have its vertical components $E_R \cos \Phi$ and $E_{R1} \cos \Phi$ in phase but its horizontal components $E_R \sin \Phi$ and $E_{R1} \sin \Phi$ in opposite phase, so as to neutralize each other, if the earth is a perfect conductor, which is generally approximately the case for very long waves. The resultant e. m. f., therefore, as measured on an antenna will be practically vertical and will be $2E_R h \cos \Phi$ when h is the effective height of the antenna.

Different conditions prevail in the case of reception on a vertical loop with its plane in the plane of propagation, as has been show by Appleton and Barnett in the paper cited. The loop current may be looked upon as due to the difference in phase of the wave where it enters the loop and where it leaves it, the resultant electromotive force being independent of the angle at which it strikes the loop and equal to $E_R \pi 2nh' \frac{l}{\lambda}$, where E_R is the field strength, λ the distance from the front to the back of the loop in the direction of propagation, $nh'l$ the area turns of the loop, and $2\pi \frac{l}{\lambda}$ the difference in phase of the wave at the points of entering and leaving the loop. As the phase of the horizontal component will be shifted 180° by reflection and as the reflected wave now passes the loop from below (see fig. 3B) the resulting e.m.f. produced in the loop by the reflected wave will be in the same direction as that due to the direct wave and the sum of the two e. m. f's will be $4\pi E_R nh' \frac{l}{\lambda}$. If we assume no abnormal polarization in the downcoming wave and that the field due to the downcoming wave is negligible

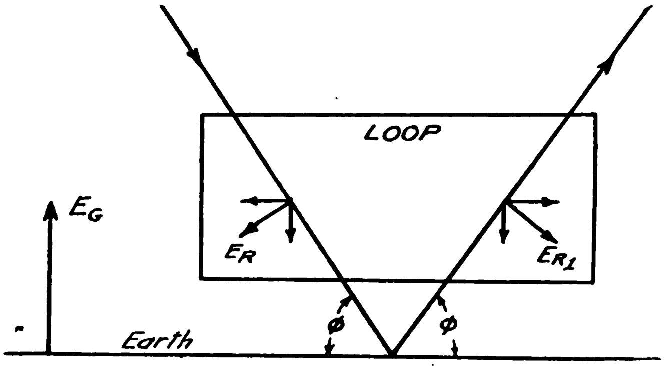

FIG. 3 B.

(*) *Royal Soc. Proc.* (A), vol. CIX, p. 621, 1925.

in comparison with the ground wave in the daytime, and that the latter remains of the same intensity by night as by day, we may determine the angle of the downcoming wave as follows: having observed the average day field intensity (ground wave alone) E_G, which will be the same for the antenna and loop, and then the average night field intensities on the antenna and loop, which will, in general, be different, we have, calling the resultant antenna field intensity E and the loop field intensity E′

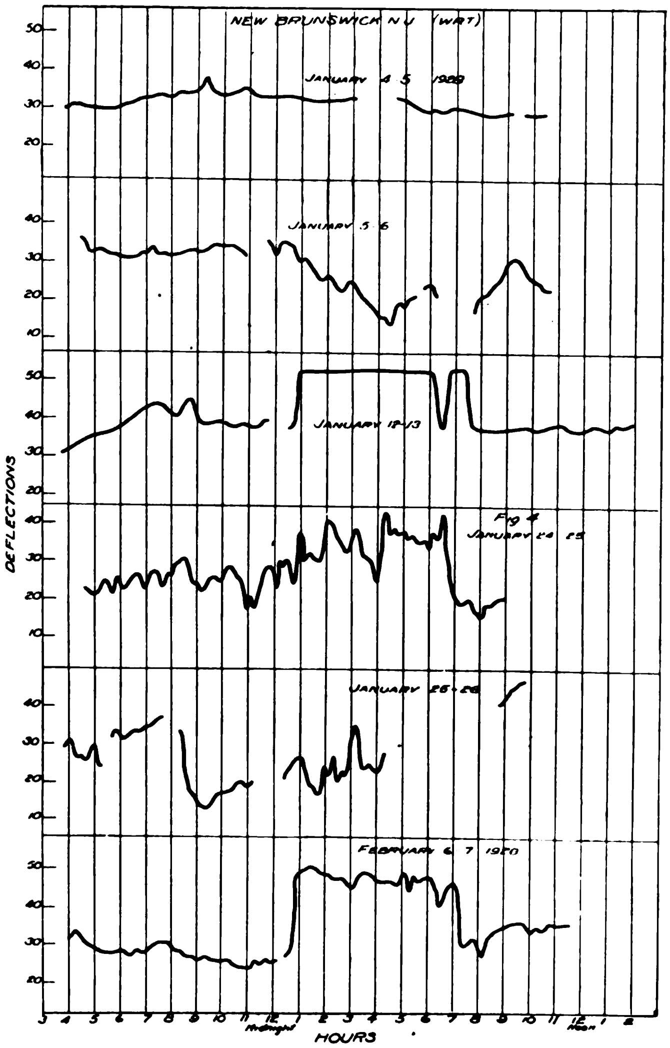

FIG. 4.

Antenna	Loop
E_D (day) $= E_G$	E'_D (day) $= E_G$
E_N (night) $= E_G + 2KE_R\cos\Phi$	E'_N (night) $= E_G + 2KE_R$

The differences in night and day field intensities is them

$$E_N - E_G = 2KE_R\cos\Phi \qquad | \qquad E'_N - E_D = 2KE_R$$

The ratio of the night and day difference of the field intensities of the antenna and loop is

$$\frac{2KE_R\cos\Phi}{2KE_R} = \cos\Phi$$

where Φ is the angle which the direction of the downcoming wave makes with the horizontal, and K a factor depending on the integral phase difference between E_G and E_R.

The accuracy of this result will be vitiated to the extent that reflection takes part in day transmission and to the extent that the ground wave varies between night and day.

Figure 4 shows the great differences which are found in the loop and antenna reception patterns from long wave stations at night, corresponding to differences in the angle of the downcoming wave. The reception shown in the figure is from WSS at Rocky Point, L. I., the distance from Washington being 435 km, and the wave length 16100 m. Since the curves of the individual days are so varied in form, an attempt has been made to use averages covering a month for determining the mean values of the downcoming wave angles at the various times of the night. It has not been found possible to determine the angle of the downcoming waves in the middle of the day, although these waves almost certainly exist, at least in winter, as is shown by the fact that the signals sometimes reach two or

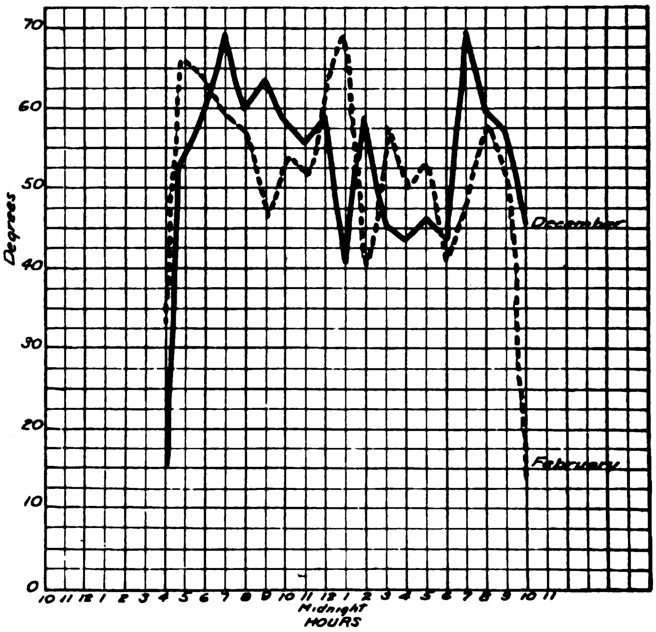

FIG. 5.

three times their calculated values. Their presence has also been indicated by the work of Hollingworth (*).

Figure 5 shows the curves of the mean values of the angle for the hours between 4 p. m. and 10 a. m. for the station WSS in the months of December 1927 and February 1928. The two curves show a rapid rise in angle about sunset, an irregular course during the night, a fall followed by a rise about sunrise, and a rapid fall to low values an hour or two later.

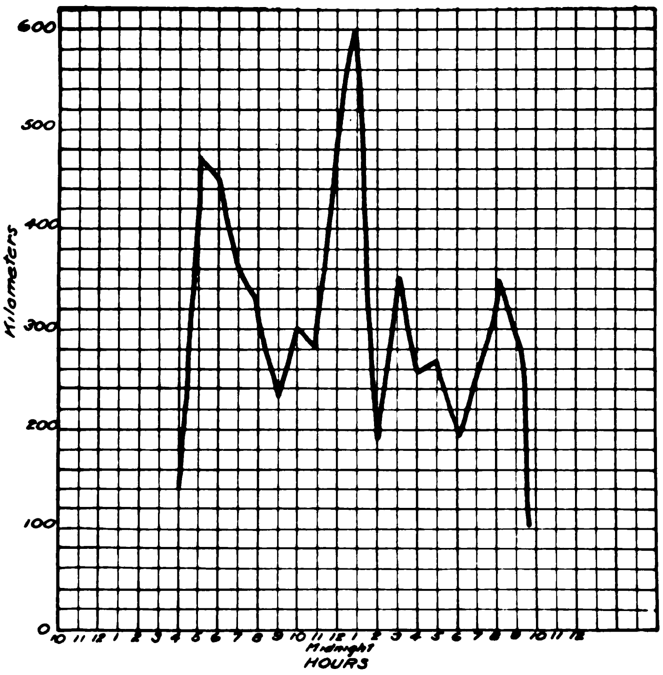

FIG. 6.

Attempted Determination of the Height of the Kennelly-Heaviside Layer. — If it were possible to assume that the downcoming wave is the result of regular reflection from a plane surface we could at once calculate the height of the reflecting layer since the distance between the sending and receiving stations is known. Figure 6 shows the average heights for the various hours of the night, for the station WSS during the month of February 1928, as calculated from the downcoming wave angles in figure 5. Figure 6 indicates a rapid rise in the height of the layer near the time of sunset, with irregular changes during the night and a fall after sunrise, corresponding to the changes of angle in figure 5. This is probably qualitatively correct, but an actual change in height from 50 to 500 km., as indicated in figure 6, would necessarily result in the intensity of the signal passing through a number of maxima and minima due to the interference of the ground and downcoming waves. These maxima and minima do not appear on the records of the recorder. If we consider the indicated height records of the individual nights, the heights calculated are seemingly preposterous, sometimes exceeding 2000 km.

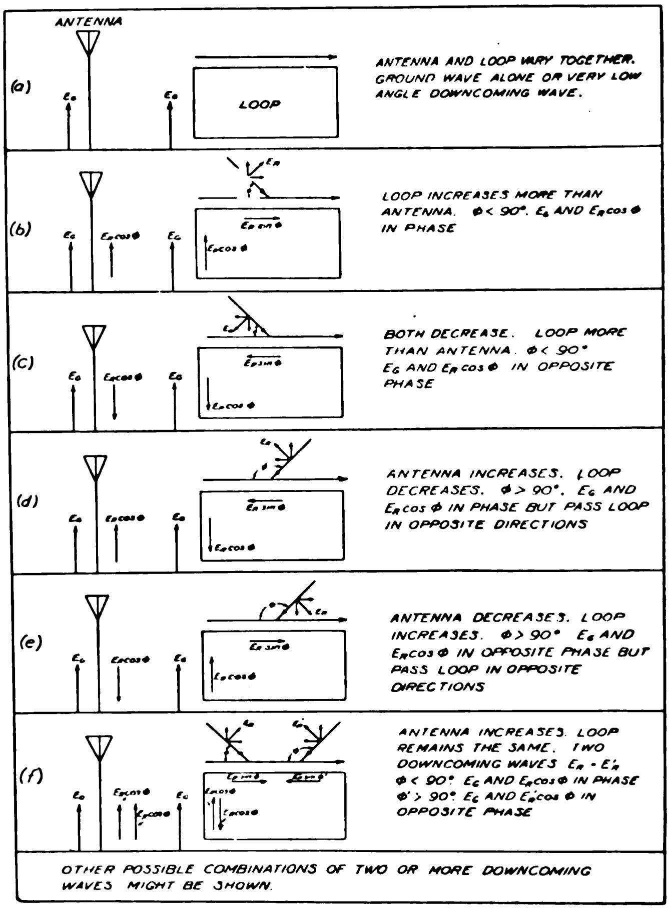
ANTENNA
(a)
E_G
E_G
LOOP
ANTENNA AND LOOP VARY TOGETHER. GROUND WAVE ALONE OR VERY LOW ANGLE DOWNCOMING WAVE.
(b)
E_R
E_G
$E_R \cos\phi$
E_G
$E_R \sin\phi$
$E_R \cos\phi$
LOOP INCREASES MORE THAN ANTENNA. $\phi < 90°$. E_G AND $E_R \cos\phi$ IN PHASE
(c)
E_G
$E_R \cos\phi$
E_G
$E_R \sin\phi$
$E_R \cos\phi$
BOTH DECREASE. LOOP MORE THAN ANTENNA. $\phi < 90°$ E_G AND $E_R \cos\phi$ IN OPPOSITE PHASE
(d)
E_R
E_G
$E_R \cos\phi$
E_G
$E_R \sin\phi$
$E_R \cos\phi$
ANTENNA INCREASES. LOOP DECREASES. $\phi > 90°$. E_G AND $E_R \cos\phi$ IN PHASE BUT PASS LOOP IN OPPOSITE DIRECTIONS
(e)
E_R
E_G
$E_R \cos\phi$
E_G
$E_R \sin\phi$
$E_R \cos\phi$
ANTENNA DECREASES. LOOP INCREASES. $\phi > 90°$ E_G AND $E_R \cos\phi$ IN OPPOSITE PHASE BUT PASS LOOP IN OPPOSITE DIRECTIONS
(f)
E_R
E'_R
E_G
$E_R \cos\phi$
$E'_R \cos\phi$
E_G
$E_R \sin\phi$
$E_R \sin\phi'$
$E_R \cos\phi$
$E_R \cos\phi$
ANTENNA INCREASES. LOOP REMAINS THE SAME. TWO DOWNCOMING WAVES $E_R = E'_R$ $\phi < 90°$ E_G AND $E_R \cos\phi$ IN PHASE $\phi' > 90°$ E_G AND $E'_R \cos\phi$ IN OPPOSITE PHASE
OTHER POSSIBLE COMBINATIONS OF TWO OR MORE DOWNCOMING WAVES MIGHT BE SHOWN.

FIG. 7.

In the examination of the individual daily curves of the loop and antenna reception from which figure 5 is derived, we find that the calculated angles of the downcoming waves are not only nearly always very high, but in many cases appear to be greater than 90°, that is, the wave comes down from the back. These observations may be explained, either by supposing that the downcoming wave is produced by

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(*) *Journal I. E. E.*, London, vol. LXIV, p. 579, 1926.

reflection from a rough surface or perhaps from irregular ionized cloudlike masses, or by refraction in a medium of very irregularly distributed ionization.

Nature of the Fields. — It may be of interest to study briefly the variations in the downcoming wave which would produce the changes on the antenna and loop which the observations indicate. This may be done with the help of the diagrams of figure 7. In these the antenna and loop are shown with the vertical and horizontal components of the electric fields acting on them. Here E_G represents the field of the ground wave assumed to be constant day and night, $E_R \cos \Phi$ the vertical component of the field of the downcoming wave, and $E_R \sin \Phi$ the horizontal component of the field of the downcoming wave.

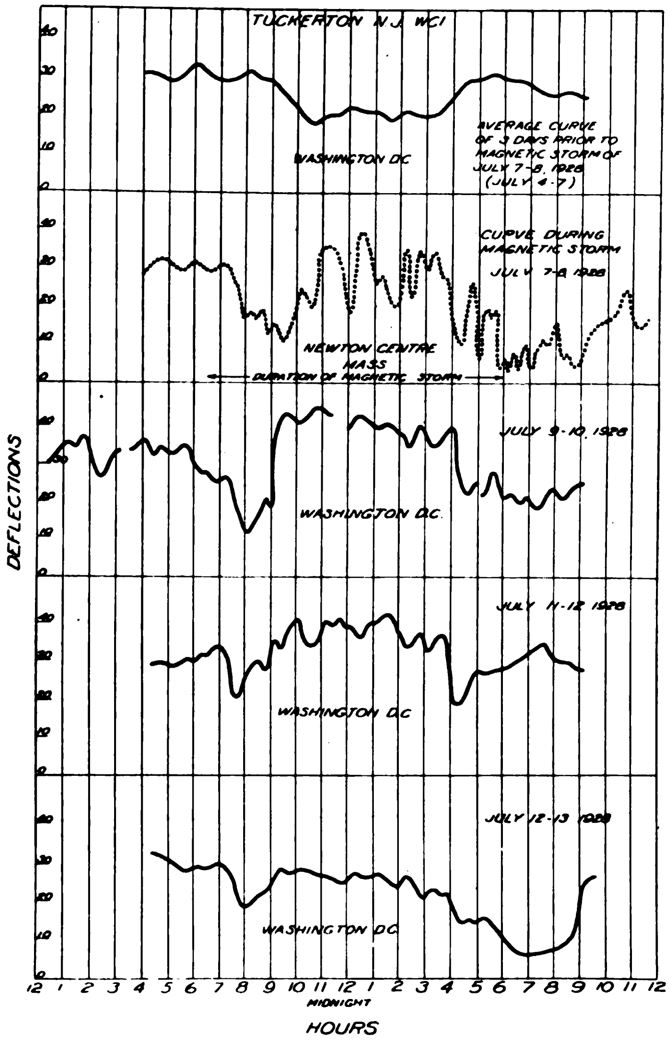

FIG. 8.

We assume that the vertical antenna is affected only by the vertical electric fields, E_G and $E_R \cos \Phi$, while the loop with its plane in the plane of propagation is affected by the total field of each wave regardless of its vertical angle. The effects of the reflection from the earth have been already explained in the discussion of the calculation of the angle of the downcoming wave, and it should be remembered that two waves passing across the loop in opposite directions produce loop currents in opposite directions.

For simplicity, in the diagrams of figure 7 E_R and E_G are considered either to be in phase or in opposite phase. The legends placed beside the diagrams will probably furnish sufficient explanations of the combinations of electric fields and the resulting changes in the antenna and loop signal intensity. All of the cases of change in antenna and loop signal intensities given have been identified in our records.

Long Wave Night Signals and Magnetic Storms. — The continuous records of the long wave signals promise more complete information concerning the relation of magnetic storms to the variations in radio transmission at these wave lengths than it has been possible to obtain from the daylight observations, which were the only ones taken regularly at the Bureau of Standards before the introduction of the recorder.

Some records taken on signals from the R.C.A. station WCI at Tuckerton, N. J., wave length 16750 m., in July 1928, are shown in figure 8. These include the period of the unusually severe magnetic storm of the night of July 7-8 and show apparently unmistakable evidence of the effects of this storm on the transmission. As no record was obtained at the Bureau of Standards on the night of the storm, Mr. G. W. Pickard has kindly permitted me to use one taken by him at Newton Center, Mass., where the curves of WCI generally agree closely in behavior with those taken in Washington. This curve is shown as a dotted line in the figure. It will be noted that if we compare the average curve of the three days before the storm, which we believe represents normal comparatively undisturbed summer conditions, with the curve of the night of the storm and those of the nights which follow, the storm appears to have caused an inversion of the general night trend, changing the slight normal drop during the night to a considerable rise. During the hours of the continuation of the storm, from 6:30 P.M. on the 7th to 6 A.M. on the 8th, the night curve is not only in general much higher than usual but very much disturbed. On the succeeding nights the irregularities of propagation gradually became less until on the night of the 12th-13th almost normal conditions had returned. Similar effects have been observed in the case of two other major magnetic storms on the signals of WCI, and irregularities have often been detected due to the minor storms noted as N° 1 days in the magnetic reports.

WCI appears to be particularly suited in wave length and in distance from Washington for showing the effects of magnetic disturbances in the night signals. Some of the other R.C.A. stations in New Jersey and on Long Island show these effects much less. These differences in behavior are perhaps to be expected when we remember that the increase or decrease of the night signal depends so much on the phase relations of the ground and downcoming waves.

Unidirectional System. — Automatic recording is also applicable to a method of reception which was first introduced by Appleton and Ratcliffe (*), for the study of downcoming waves and which was independently used for the same purpose a little later at the Bureau of Standards.

In this method the well known combination of a loop with a vertical antenna for the elimination of signals from a given direction is employed, in which the strength of reception from different directions in the horizontal plane takes the form of a cardioid.

This circuit, often called the barrage circuit in America, has long been used for the elimation of undesired signals and for the reduction of atmospherics. The circuit arrangement is shown in figure 9. Here the loop is turned on its vertical axis so that its plane is in the plane of propagation, but is so coupled to the antenna that the reception from the given direction on the loop opposes that on the antenna. Then the strength of coupling L L′ is adjusted so that in the middle of the day, when it is supposed that only the vertical ground wave is present, the two receptions balance and no deflection is shown on the recorder. If these conditions are fulfilled, the system is balanced for all vertical fields of the given frequency from the given direction for which the adjustment was made. If, however, as sunset approaches, or during the night, downcoming waves appear, their horizontal components of field will destroy the balance and deflections will be produced.

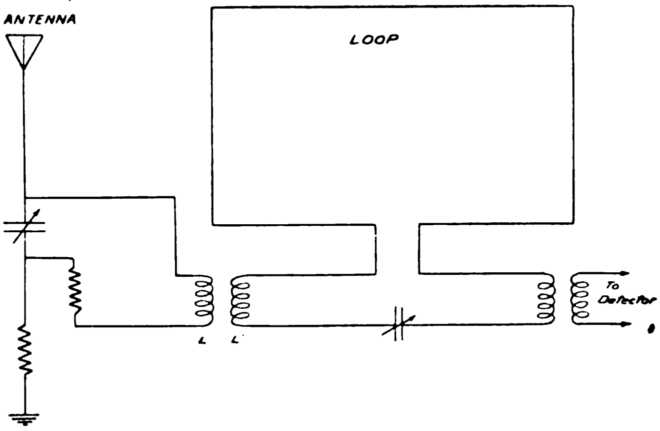

FIG. 9.

Calling E_G the electric component of the field due to the ground wave and E_R that due to the downcoming wave, the effect of the antenna on the receiver is proportional to $E_G + KE_R \cos \Phi$, and of the loop $E_G + KE_R$ as was shown in the discussion of the angle of the downcoming wave. Since the loop and antenna are adjusted so as to produce equal and opposite effects on the receiver in the case of the reception of the ground wave, the resultant effect on the receiver when downcoming waves occur is

$$E = A\,(E_G + KE_R - E_G - KE_R \cos \Phi)$$

$$= AKE_R\,(1 - \cos \Phi) = 2AKE_R \sin^2 \frac{\Phi}{2}.$$

The advantage of this system over that in which the antenna and loop are used separately is that here we are able to study the downcoming wave free from the ground wave although modi-

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(*) *Proc. Roy. Soc.* (A), vol. CXV, p. 291, 1927.

fied by K, the factor due to the phase difference between E_G and E_R.

Figure 10 shows two curves of reception of the R.C.A. station WRT ($\lambda = 13200$ m.) at New Brunswick, N. J. as recorded in Washington on the night of April 2-3, 1928. The solid curve represents reception on the loop and the dotted curve that on the unidirectional system. The sensitivity of the unidirectional system is about four times that of the loop. It will be noticed that the variations in the two curves generally, but not always, follow each other.

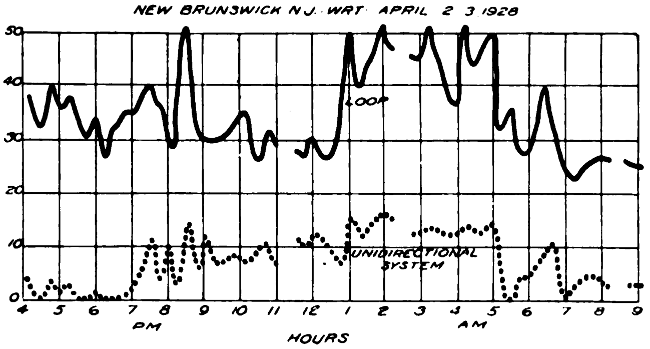

FIG. 10.

Our knowledge of the conditions in the upper atmosphere which affect the radio waves as they pass through it to the receiving station is still very fragmentary.

The impression which is gathered from the large number of records of reception at wave lengths above 10,000 m., taken by the automatic recorder, does not by any means support the view that the bending of the waves in the upper regions is due to any approximately regular reflection or refraction.

The somewhat confused picture which we have gained is rather that of rapidly changing masses of ionized gas forming an extremely irregular and shifting lower surface if we are dealing with reflection and possibly with openings through which the rays may pass at times to higher levels before being turned back toward the earth.

FURTHER STUDY OF THE RELATION OF RADIO WAVE PROPAGATION TO DISTURBANCES IN TERRESTRIAL MAGNETISM

by I. J. WYMORE.

That a relationship exists between the propagation of radio waves on the one hand and disturbances in terrestrial magnetism and variations in the activity of the sun, on the other, now seems reasonably certain. This has been clearly shown when the observations are averaged in periods of a month or more (1-7).

Observations taken at night show a peculiar reversal in the relationship between radio transmission and solar and magnetic phenomena and those taken during daylight. Increase in solar activity and magnetic disturbances appears to increase the radio signal strength in the daytime, but to cause a decrease at night. Short period comparisons have been made by several observers, making use of simple averages of a few days, 27-day periodic averages and moving averages. These, while they frequently show a very satisfactory degree of correlation over considerable periods, at times get out of step. In some cases the radio changes appear to lead, while in other cases they gradually lag behind the corresponding solar or magnetic variations.

In the present paper a study has been made of the relationship of long-wave radio reception to measures of magnetic activity over short periods. The well known method employed has been also used by Mr. Pickard for similar comparisons in the broadcast range.

The field intensity measurements employed are those made on the distant stations Lafayette

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(1) ESPENSCHIED, ANDERSON ET BAILEY, *Proc. I. R. E.*, vol. XIV, p. 7, 1926.

(2) G. W. PICKARD, *Proc. I. R. E.*, vol. XV, n° 2, p. 83, 1927

(3) ID. *Ibid.* vol. XV, n° 9, p. 749, 1927.

(4) ID. *Ibid.* vol. XV, n° 12, p. 1004, 1927.

(5) L. W. AUSTIN, *Proc. I. R. E.*, vol. XV, n° 10, p. 825, 1927.

(6) ID. and I. J. WYMORE, *Proc. I. R. E.*, vol. XVI, n° 2, p 166, 1928.

(7) C. N. ANDERSON, *Proc. I. R. E.*, vol. XVI, n° 3, p. 297, 1928.

(LY), Ste-Assise (FT and FU), Nauen (AGS and AGW), Rugby (GBR), Coltano (ICC), and Bolinas (KET) taken from 10:00 A. M. at the Bureau of Standards and those on stations less than 500 km distant, at Tuckerton (WGG), New Brunswick (WRT, WII), and Rocky Point (WSS) at 10:00 A. M. and 3:00 P. M. The field intensity of long radio waves is known to be less influenced by magnetic storms than those in the broadcast range. For this reason, only the more severe disturbances, that is, only days when the magnetic character was reported as 2 at Cheltenham Ind. were considered as magnetically disturbed days in the calculations. Averages were made of the signal strength of the corresponding days covering a period of eleven days centering on the day of the disturbance.

The following table gives the dates of the magnetic storms considered in the calculations.

1925		1926		1927	
January. .	19-20	January. .	26-27	March. . .	28
June. . . .	13	February .	23-24	April . . .	14
June. . . .	24	March. . .	5	May. . . .	5
July. . . .	26	April . . .	14-16	July. . . .	21-22
August . .	22-23	May. . . .	4-5	August . .	20-21
September	1-2	June . . .	1-2	October. .	10
September	14-15	September	9	October. .	12
September	21	September	15	October. .	22-23
October. .	23-24	September	20-21		
November	9	October. .	14 16		

Figure 1 shows the percentage deviations from the A. M. monthly averages of the long-wave European stations (LY, FU, AGW and GBR) during the time of greatly increased activity of the sun in 1925, 1926 and 1927. The trend of the curves before the zero day of the storm varies somewhat in the three years although in general it tends to lie below average. The most striking similarity is in the high values on all the curves on the second day after the peak of the storm. That this effect is definitely related to the magnetic disturbance is further evidenced by the behavior of the signals at the time of one especially severe storm, that of October 12, 1927 (fig. 2). Intensities well above normal were observed on October 12 and October 14 but on the latter date the intensity was so greatly increased that in some cases it was over 200 % above the

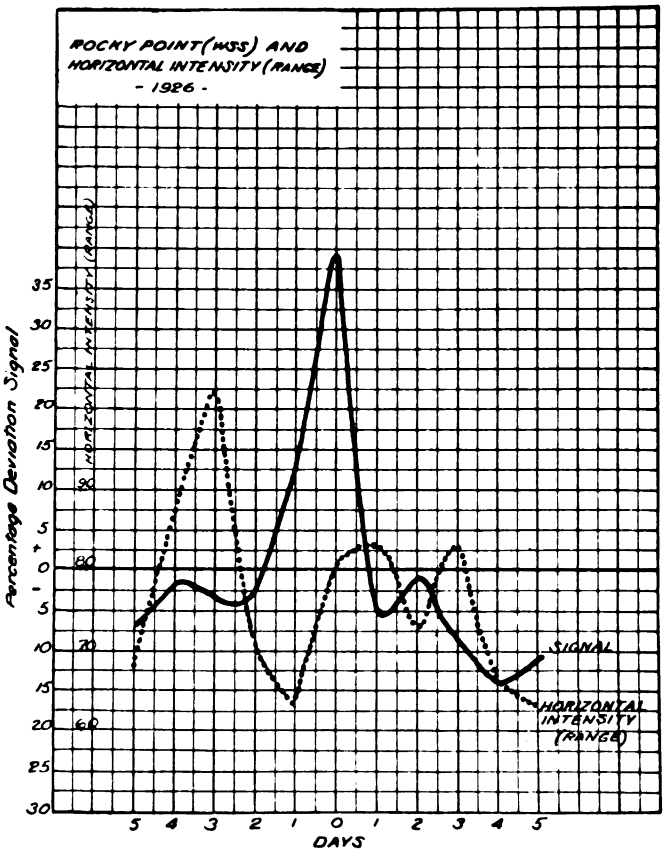

FIG. 1.

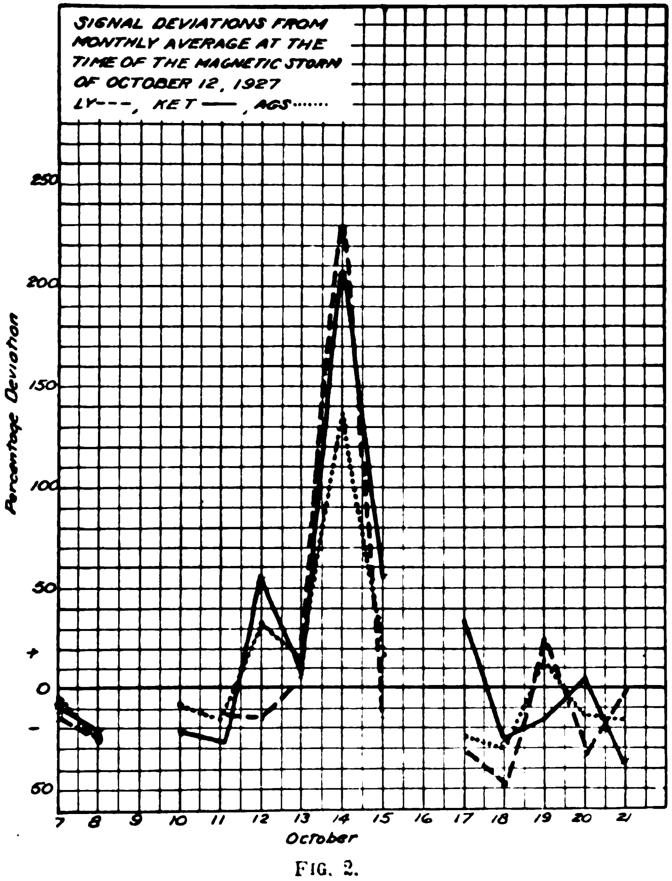

FIG. 2.

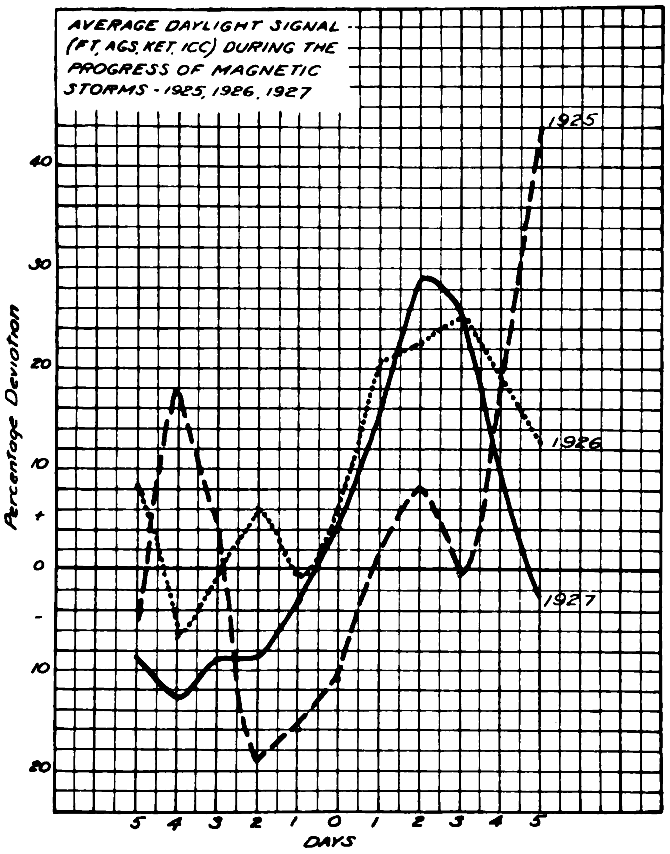

FIG. 3.

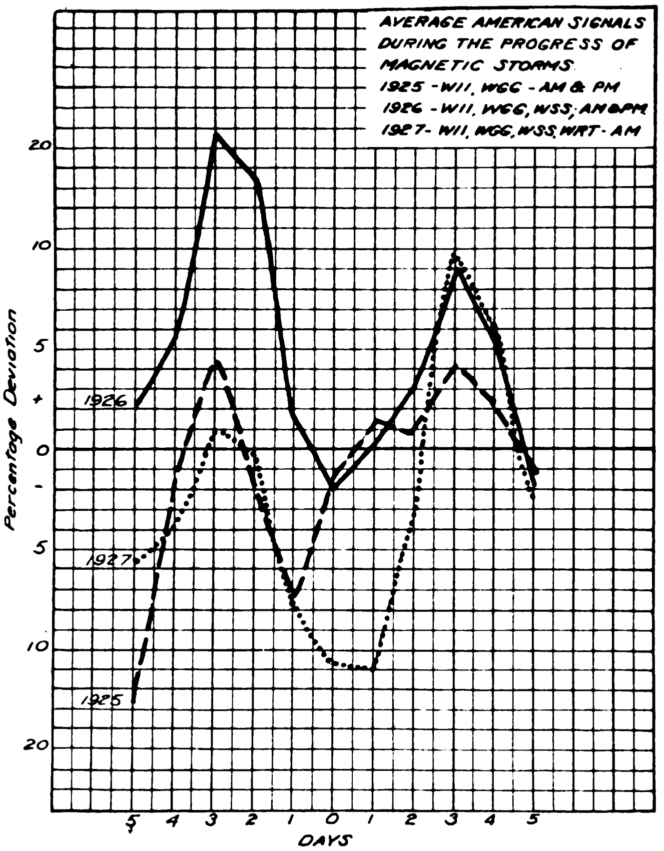

FIG. 4.

average value for the month. This increase in signal strength is too great to be a recovery from an abnormal condition before the storm and so must represent some real effect of the condition productive of the magnetic disturbance.

In figure 3, A. M. averages of AGS, FT, KET and ICC are given for the same years. The same general tendency is noted in these curves with the exception of 1925, which shows high values on both the fourth and fifth days after the storm.

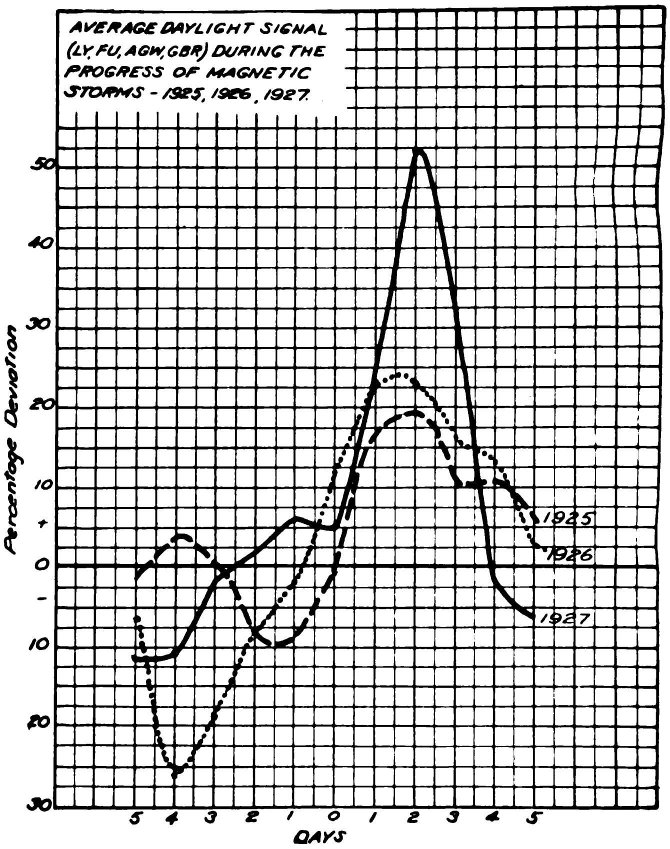

FIG. 5.

Curves of averages of field intensities of American stations at moderate distances (WII, WGG, WRT and WSS) have somewhat different characteristics from those of European stations. Averages of these signals for the years 1925, 1926, 1927 are shown in figure 4. These show in general a depression of signal strength below normal on the day of the storm preceded three days before by a considerable rise in signal intensity and followed three days after by another increase. Curve 1 of figure 4 is an average of WII and WGG, both A. M. and P. M., 1925; curve 2 of WII, WGG and WSS, A. M. and

P. M. for 1926, and curve 3 an average of WII, WGG, WRT and WSS, A. M. only for 1927.

As a check on the foregoing results, averages were made of the magnetic horizontal range covering the same period of time (11 days) but centering on the day the signal intensity rose 25 % or more above the average of the month. In figure 5 these averages are shown for WSS 1926. As would be expected from the foregoing results, high values of horizontal intensity (range) occurred three days before and two to three days after the signal peak.

From the foregoing analysis it is evident that during periods of magnetic storms the behavior of long wave day-light signals tends to be as follows :

1. Over long distances :

Intensity below normal for several days (0-5) before the disturbance followed by a definite increase in strength one to three days after the storm.

2. Over moderate distance :

An increase above average in signal strength two to four days before the magnetic disturbance with values below normal during the height of the storm followed by a strong increase in intensity two to four days after the storm.

This work was done under the direction of Dr. L. W. Austin at the Laboratory of Special Radio Transmission Research, Bureau of Standards. The observations used were made by Mr. E. B. Judson. July 23, 1928.

READABILITY OF LONG DISTANCE RADIO COMMUNICATIONS

by T. NAKAGAMI and C. ANAZAWA.

Department of Communications, Japan.

The observations of the long distance radio communications were made for many years in Japan, but they were not carried on throughout 24 hours continuously owing to the various circumstances.

Since last year many chances for the continuous whole day test were offered and the authors should like to communicate the results of these for the benefit of further investigations.

The readability curves of the trans-continental communications are shown in the figures 1, 2 and 3.

The figure 1 is the result of the receiving test carried out in Japan of the beam station of England. It was reported that the GLX beam was directed to Japan and the GLY directed in the opposite direction. The reception was made at the four receiving stations and their results are nearly the same with respect to the readable hours. These curves show the fact that both the GLX and the GLY are subject to substantially the same diurnal variation. The condition with regard to the day-time and night-time throughout the path of the wave is indicated beneath the curve. The space between the abscissa J. S. T. and G. M.T. is the condition between Japan and Europe via Siberia while the space between G. M. T. and J. S. T. is the condition between Japan and Europe via the opposite direction. The shaded space indicates the night-time and the unshaded space, the day-time.

The readability is the maximum when the day-time or the night-time prevails over the shortest path between Japan and Europe and drops to nil by the encroachment of the sunset in Japan and the sunrise in Europe. The unreadable hours of GLY are longer than those of GLX.

The receiving set used in these tests consisted of one oscillator-detector and two audio amplifiers.

Figure 2 represents the readability of the long wave of the Nauen station at Nagoya in Japan throughout 24 hours in March and the figure 3 is that of May, 1928.

In March the readability is maximum when the night-time prevails throughout the path. In May there is no time when the night-time prevails throughout the path and therefore the maximum readability occurs when the path is half covered by the night-time, and this maximum is not so good as that of March. In both curves the readability falls to the minimum at the time when the path is covered by the daytime. Besides, the signal intensity has the falling tendency at the sunrise of the receiving station. For these tests the Telefunken long wave receiving set with double goniometer antennae was employed.

The figures 4, 5 and 6 are the readability

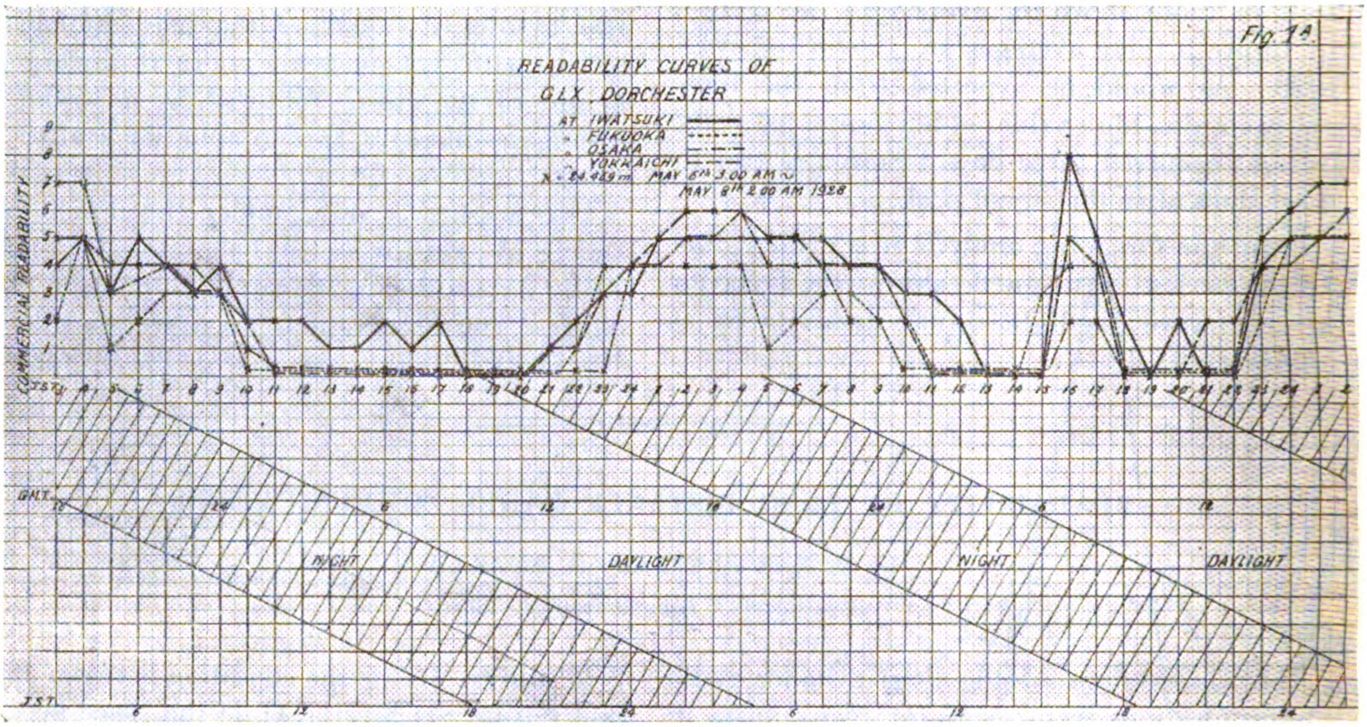

FIG 1 A.

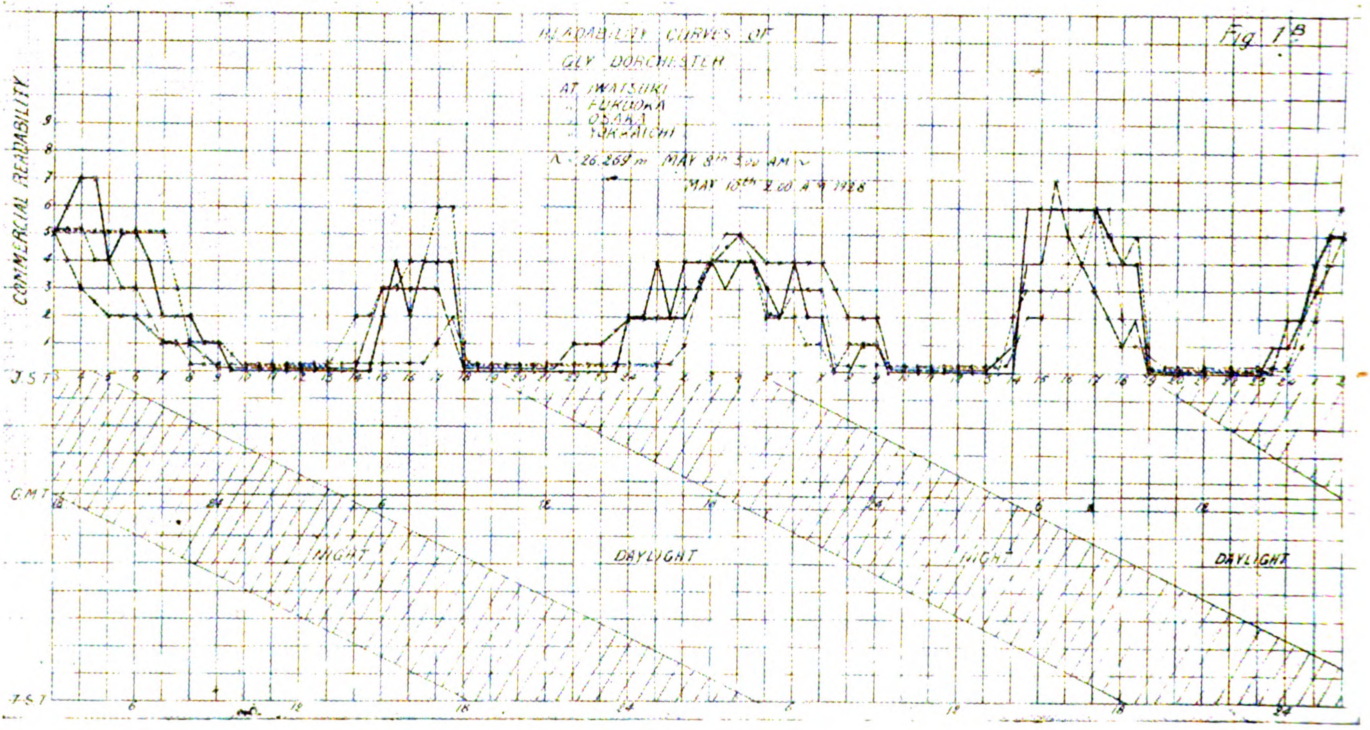

FIG. 1 B.

curves of the Japanese short wave station, the reception having been made at Chelmsford and Somerton in England. The 42 metres wave is heard only when the path is covered by the night-time, and the 24 metres wave has the readability curve similar to that of GLX received in Japan. The 16 metres wave is unheard only a few hours in a day, the course of which is not clear and therefore further experiments must be made on this short wave band.

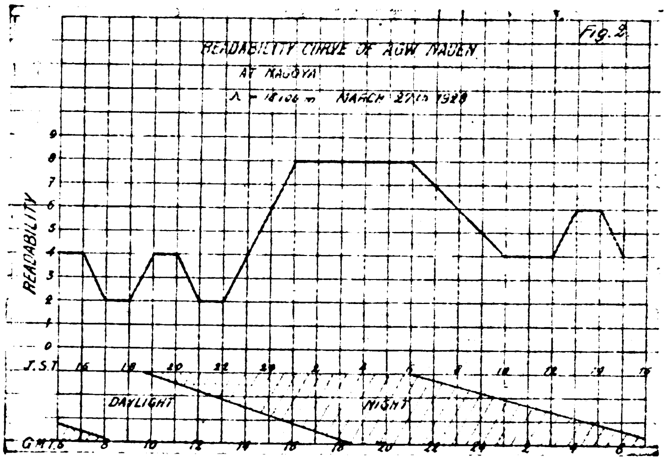

FIG. 2.

The readability curves of the Trans-Pacific communications are shown in the figures 7 to 11.

The figure 7 is the average result of the tests of the Tomioka (JAN) received at Marshall, Calif., during, April 2-17, 1928 on 41 metres. The signals rise to the maximum when the Pacific is covered by the night-time and drops to zero when it is covered by the day-time. When the night-time covers a part of the Pacific, the intensity rises in proportion to the width of the darkness throughout the path. The readable hours of the 24 metres are much broader than those of 41 metres (see fig. 8), but the maximum readability occurs again when the Pacific is covered by the night-time and drops to the minimum when the day-time covers the Pacific.

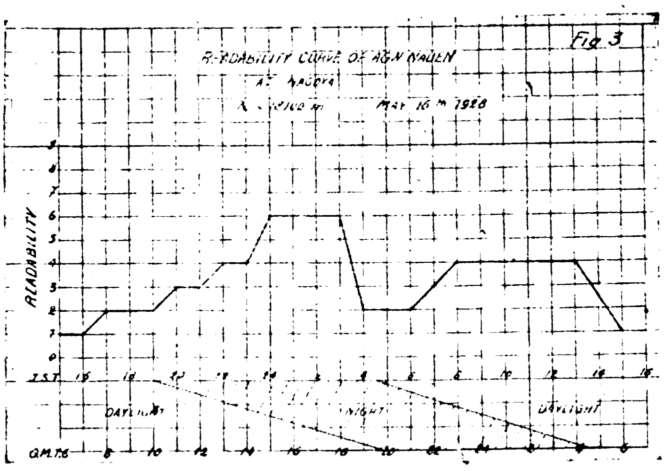

FIG. 3.

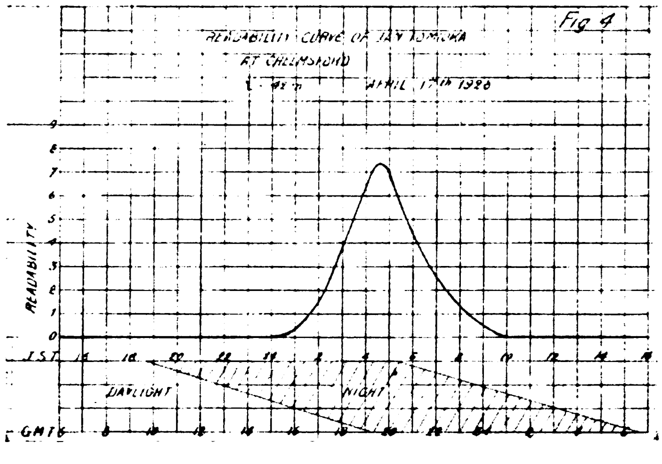

FIG. 4.

The figure 9 shows the result of the 24 hour test of the Bolinas station received at Iwatsuki Japan on 29, 3 metres. The shape of the curve resembles that of the figure 8, although the direction of the propagation is contrary to that of the above tests.

The readability for the 16 metres, however, is quite different and the averages result of the test is shown in the figure 10. The maximum readability occurs when the sunset approaches

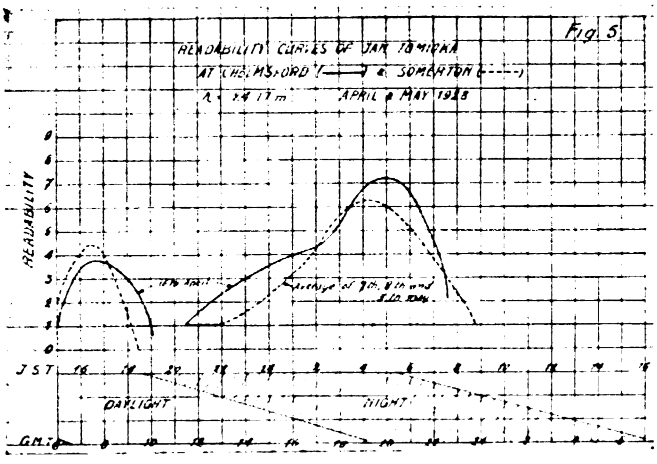

FIG. 5.

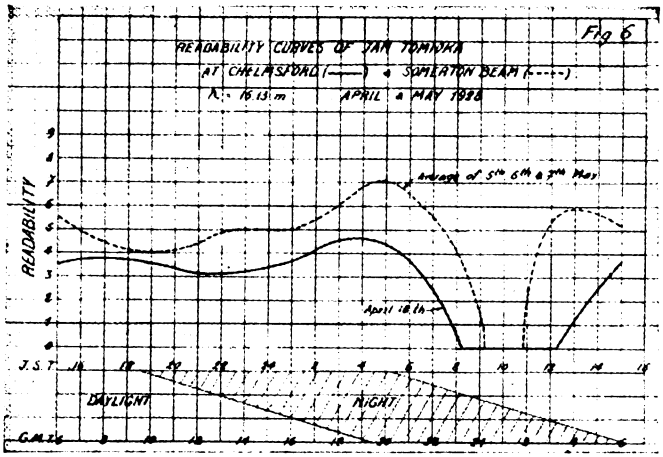

FIG. 6.

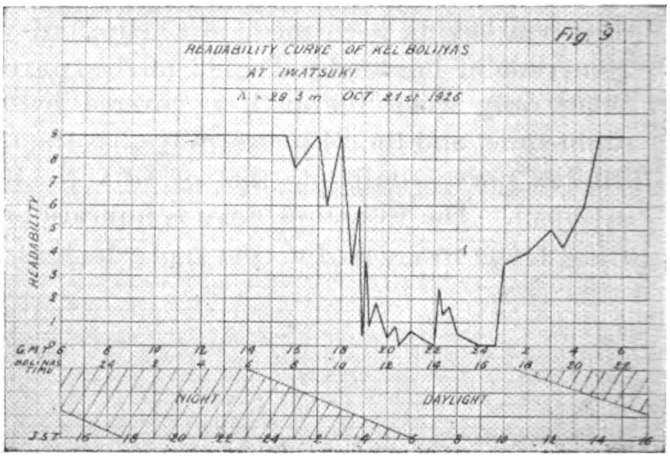

FIG. 9.

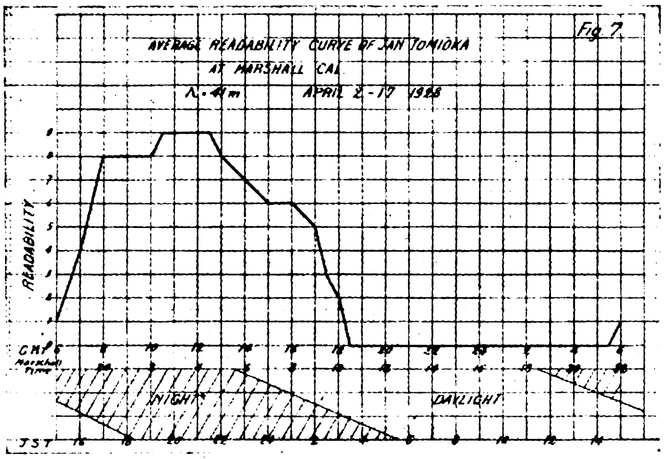

FIG. 7.

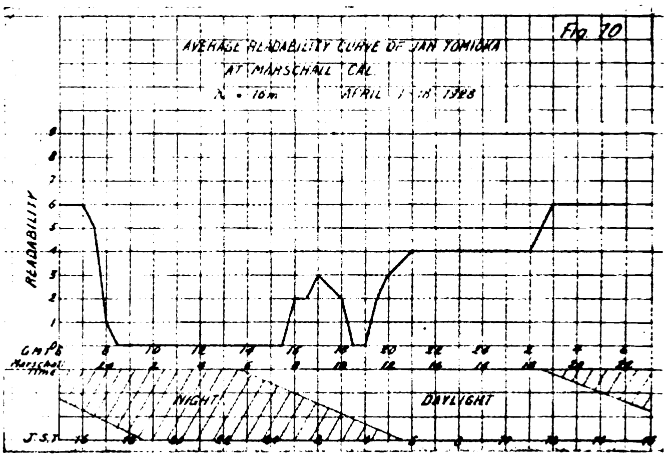

FIG. 10.

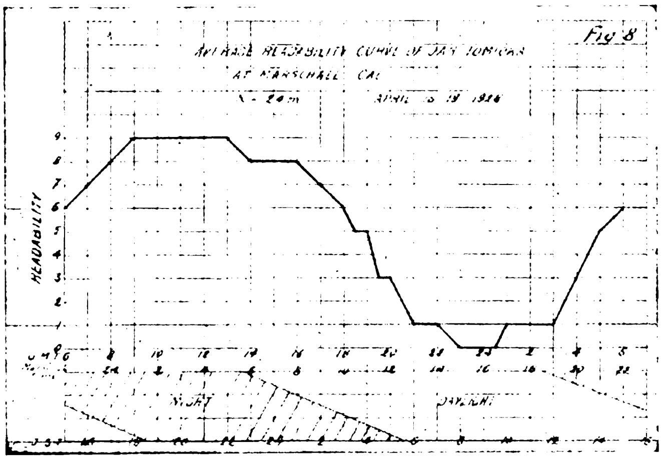

FIG. 8.

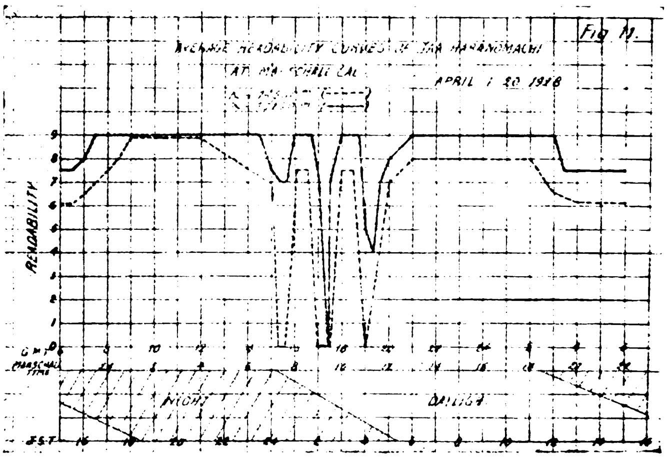

FIG. 11.

the receiving station and drops to the minimum when the Pacific is covered by the night-time; when the Pacific is covered by the day-time the readability does not reach the maximum but it continues in the steady readable conditions.

The figure 11 is the average result of all day tests across the Pacific on long waves transmitted from Iwaki, Japan, and received at Marshall, Calif. The full line curve is that of the arc transmitter and the dotted line curve is that of the arc transmitter. The generator feeds the antenna at 450 amperes and the arc at 200 amperes. The readability for both transmitters falls three times between the sun rise of the transmitting and the receiving station; the arc being weaker drops to zero at these periods.

SOME OBSERVATIONS OF SHORT-PERIOD RADIO FADING (*)

by T. PARKINSON,

Associate Physicist (Bureau of Standards).

SUMMARY. — The data presented are the product of an investigation started at the beginning of 1928 with the object of studying the short-period fading of radio broadcast transmissions. Particular attention was paid to those intensity changes which take place during periods ranging from a few seconds to several minutes. Various antenna combinations were used in making simultaneous records in order to separate the effects of various causes of fading.

It was concluded that in addition to the more commonly accepted causes there may be a number of indirect rays with varying paths and with rotating planes of polarization which give rise to the variations in intensity of the received signal. Some of the conclusions are consistent with those of other workers in the field but new explanations are necessary for some of the data.

Introduction. — The data presented in this paper are the product of an investigation started by the Bureau of Standards at the beginning of 1928 with the object of studying the short-period fading of radio broadcast transmissions. This study was directed particularly to those intensity changes in the receiving antenna which range, in period, from a few seconds to several minutes between peaks. These variations have been variously ascribed by previous investigators to one or more of the following causes: 1° intensity changes undergone by the indirect or atmospheric ray, namely, that portion of the radiation which, at night especially, travels to the upper atmosphere and is returned to earth at the receiving antenna by reflection or refraction; 2° interference, due to varying phase relationships of two or more indirect rays or of an indirect ray and the ground ray, which follows a direct path along the surface of the earth from the transmitting to receiving antenna; 3° direction shifts, this expression being used to connote deviations of the indirect ray from the great-circle plane passing through transmitting and receiving points; 4° changes in the angle of incidence, that is, in the vertical plane of arrival of the indirect ray; 5° rotation of plane of polarization of the atmospheric ray, this rotation being considered as a continuous process rather than in the optical sense of a definite displacement of the plane at completion of the process. The aim of the present investigation was first of all to separate the effects due to the above-mentioned causes with a view to determining to what extent each might be a factor in fading.

The method consisted in selecting a particular broadcasting station and making simultaneous graphic records of its carrier wave as received by different types of antennas attached to duplicate receiving sets. The antennas used were: 1° a vertical single-wire 15 meters high with a 2-meter horizontal lead-in; 2° a vertical coil having its turns in the great-circle plane

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(*) Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

common to transmitting and receiving points, which coil will hereafter be referred to as « at maximum », or « in the maximum position »; 3° a vertical coil perpendicular ,to the above, and hereafter to be designated as « at minimum », or « in the minimum position »; 4° a so-called barrage antenna, consisting of the single-wire antenna so coupled to a coil antenna in the maximum position as to introduce an out-of-phase current and thus neutralize the effect of the ground ray as well as of the vertical component of the indirect ray. The coil antennas were so balanced by a center tap arrangement as to eliminate any appreciable « antenna effect ». For all tests the various antennas were located from three to five meters apart. These distances were sufficiently small so that records obtained simultaneously with similar antennas were alike, and were sufficiently large to prevent interaction between the separate receiving circuits. All observations were made at the Bureau of Standards field station located at Kensington, Maryland, 8 kilometers north of the Bureau and in a position practically free from man-made interference and distorting influences.

Other apparatus employed was essentially that described by G. W. Pickard (1) (*) in 1923 and used later in the cooperative investigation conducted by the Bureau of Standards in 1925 (2). The receiving sets were superheterodynes of the same make and were capable of adjustment to practically the same amplification. The driving motors of the Shaw manual recorders were automatically synchronized every second, thus making it possible to compare two records by superposition.

Observations were concentrated largely upon two stations, but less frequent records were made on transmissions from other stations involving frequencies of 550 to 1,480 kilocycles and direct transmission paths of 13 to 1,500 kilometers. The greater number of records were made upon WJZ, Boundbrook, N. J., and upon WBAL, Baltimore, Md., because of the regularity with which each could be received, day or night, and because of what appeared to be characteristic features. Many of the observations started during daylight when there was no appreciable indication of an indirect ray, and when consequently the most accurate bearings could be secured with the coil antennas. At this time, also the two receiving systems could be so adjusted that the ground wave produced the same deflection on the recorder galvanometers of the two receiving systems. When records were started after dark no attempt was made to have them on an accurately comparable intensity basis, the chief aim being to study the simultaneous changes on two records rather than their exact magnitudes.

The arrangement of the pairs of simultaneous records in the illustrations will be found somewhat inconsistent since the character of the records made it easier to compare them by placing the one made with a given type of antenna sometimes above, sometimes below, the record made with another type.

Conclusions of Previous Investigations. — Both Pickard, in his 1923 investigation (3), and Appleton and Ratcliffe in their recent work (4) have given the chief credit for fading to intensity changes undergone in the path of the indirect ray. Pickard ascribes these changes to varying absorption and suggests a possible explanation, while Appleton and Ratcliffe find reason to suspect that interferences between rays travelling by multiple paths are the cause. These authors agree also in crediting interference between ground and indirect rays with a minor role in causing fading; and practically eliminate direction shifts as a factor. Appleton and Barnett (5), as well as Smith-Rose and Barfield (6) had previously satisfied themselves that apparent direction shifts were due chiefly to elliptical polarization of the atmospheric ray, and very little, if at all, to actual changes in lateral angle with the great circle plane through transmitting and receiving points. Pickard did not discuss changing angle of incidence nor rotation of the plane of polarization of the downcoming ray in connection with his fading data. Appleton and Ratcliffe were unable to detect any evidence that these factors were affecting fading (7) in spite of the fact that rotation of

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(*) See page 118.

the plane of polarization of the incident ray had been accepted as explanation for apparent direction shifts. The Bureau of Standards reports (⁸) on cooperative measurements in 1925, while accepting varying absorption as the more general cause of fading, gave considerable weight to interference effects so far as fading of nearer stations was concerned, but no data bearing upon the other factors were then secured.

While the present paper deals only with observations in the broadcast range of frequencies and with limited methods of analysis it is well to have in mind the conclusions reached by investigations at other frequencies and by other methods. Working particularly with frequencies above 3,000 kilocycles Breit and Tuve (⁹) found fading occurring independently of interference between ground and indirect rays and suggested multiple reflections and flickering effect due to wavy character of surface of the ionized region. Heising (¹⁰) as well as Taylor and Young (¹¹), using an oscillographic method similar to that of Breit and Tuve found proof of a multiplicity of paths of different lengths. Heising found these regularly accompanied by fading and simultaneous with an apparent rising of the ionized layer. Rukop (¹²) in working with transmission of pictures at high frequency had earlier secured evidences of multiple paths which were accompanied by fading which, however, was not necessarily associated with the multiplicity of paths. The path length changed at times as rapidly as 50 km a second giving the Doppler effect of a change in frequency at the receiving system. From theoretical considerations Pedersen (¹³) concluded that there should be an infinite number of downcoming rays at a given point on the earth's surface.

Fading produced by interference was found by Bown, Martin and Potter (¹⁴) in an oscillographic study of the distortion in broadcast reception within a given area, and oscillographic observations by Friis (¹⁵) of reception on 18.75 megacycles proved consistent with the belief that fading is mainly caused by wave interference.

Very good evidence of real direction shifts was found by Friis (¹⁵) using a cathode ray oscillograph to observe the phase difference of signal waves as received by antenna systems located a fraction of a wave length apart.

Changes in angle of incidence were found by Friis (¹⁵) to be much more frequent and of greater magnitude than direction shifts of the received signals. Heising (¹⁰), by his observations of signal retardation, had previously computed changes in angle of incidence sufficient to indicate rapid variations in the height of the ionized layer, sometimes as great as 72 kilometers (45 miles) in two minutes.

Rotation of the plane of polarization of the indirect ray was suggested from theoretical considerations of the earth's magnetic field and varying ionization in the upper atmosphere by Appleton and Barnett (¹⁶) and by Nichols and Schelleng (¹⁷), who indicated that this phenomenon might be expected in transmissions largely along the line of a magnetic meridian. Evidences of abnormal polarization causing apparent direction shifts were pointed out by Eckersley (¹⁸), and Pickard (¹⁹) found by many observations made on high frequencies with an analyzer that the plane of polarization under certain conditions rotated 90° in transit. Alexanderson's investigation (²⁰), also on the high frequencies, seemed to indicate a continuous rotation of the plane of polarization with alternate points of plane and circular polarization along the transmission path. Hollingworth (²¹) recently made measurements to determine the state of polarization of the indirect ray which produces apparent progressive direction shifts during the sunset period, and on the basis of several assumptions calculated that the plane of polarization of an indirect ray received from a selected transmission of 21,622 kilocycles rotated 90° during sunset and remained thus abnormally polarized during the night. Eckersley (²²) working with the high frequencies, made simultaneous fading records with horizontal and vertical antennas and reports that under some conditions the fading changes in the two records were so nearly opposite in phase as to indicate rotation of the plane of polarization of the downcoming ray.

Simultaneous Coil and Vertical Single-Wire Antenna Records.—The first method of analysis in the present investigation was by means of simultaneous fading records made with coil antenna in maximum position and with vertical single-wire antenna, respectively. Assuming both ground and reflected rays to be in the great circle plane which passes through transmitting and receiving points, certain effects were anticipated. The ground ray presumably remains normally polarized at night as during daylight; therefore, so long as there is a normally polarized component of the indirect ray any changes in the path length of the latter should result in changing phase relations between the two rays and consequently in similar intensity variations in the two types of antenna. Since the total electric vector in the vertical plane is effective on the coil antenna the signal-strength in it should range between the sum and the difference of the two fields produced by direct and downcoming rays, respectively. On the vertical single-wire antenna similar variations should be of less absolute magnitude since only the vertical component of the electric vector is effective and this component decreases with the angle of incidence. With either antenna the night intensity, for non-local stations at least, will sometimes exceed, sometimes fall below, the relatively constant daylight level.

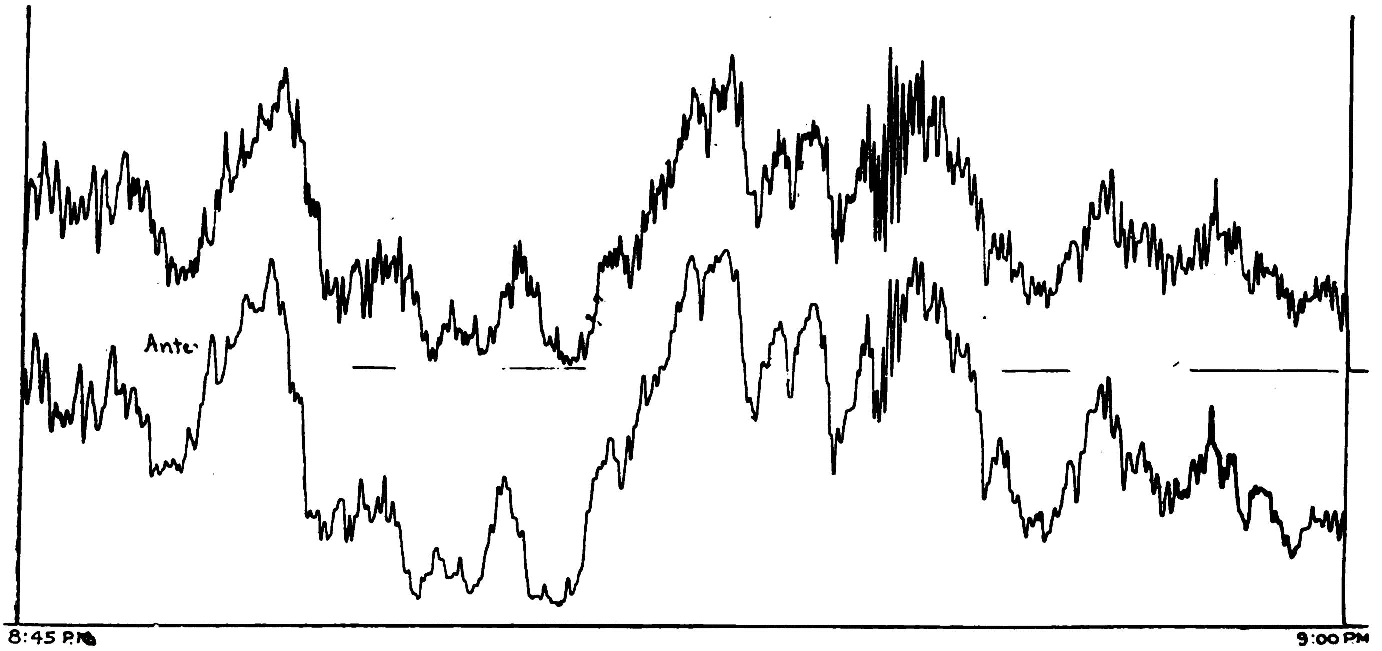

FIG. 1.

WIOD (1210 kc), Miami Beach, Florida, received at Kensington, Md., 1,500 km., March 15, 1928. Upper record with vertical antenna; lower record coil antenna at maximum.

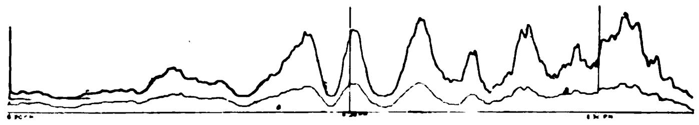

FIG. 2.

WJZ (660 kc), Boundbrook, N. J., received at Kensington, Md., 300 km., May 15, 1928. Upper record, coil antenna at maximum; lower record, vertical antenna.

Turning now to the data and examining some fifty records involving transmission frequencies of 660 to 1,480 kilocycles and distances of 13 to 1,500 kilometers, what do we find? For stations more than about 150 kilometers distant from the receiving antennas the results were practically as anticipated, as the typical graphic records of figures 1-3 indicate. There is a slight shifting of phase at one point in the WIOD record which may be real or may have been caused by changing speed of one recording drum at a time when there was difficulty with the synchronization of the two drums. Conditions prevented making another record on this station. With this single exception the intensity changes are in phase on the two antennas. An anomaly appears, however, in the records for the nearer group of stations, 13 to 53 kilometers distant, in that the fading changes are at times as much as 180° out of phase on the two records. This holds true for variations of a few seconds duration as well as for those having periods of a minute or two. Figures 4-7 show typical illustrations. Here we have the same effect that Appleton and Ratcliffe (23) found in simultaneous records made with vertical single-wire antenna and with the ground ray suppressed in a single turn loop placed in the maximum position. They accounted for the recorded differences by an interference between indirect and ground rays which was effective in the vertical antenna but was eliminated from the loop. This explanation is not applicable to the present data since with the ground ray effective in both antennas there is still a lack of synchronism in the fading of the two records. Appleton and Rat-

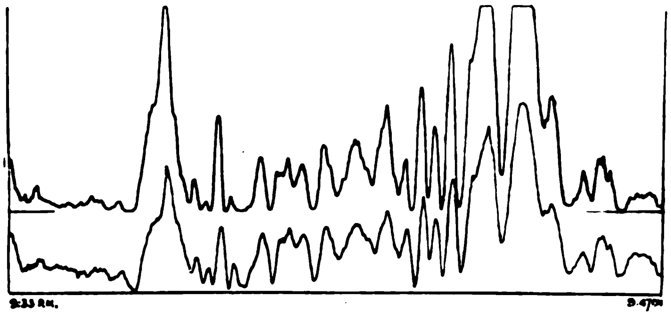

FIG. 3.

WRVA (1180 kc), Richmond, Va., received at Kensington, Md., 155 km., June 1, 1928. Upper record, coil antenna at maximum; lower record, vertical antenna.

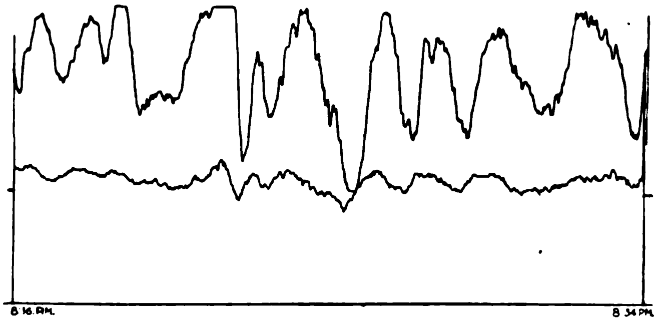

FIG. 4.

WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., May 9, 1928. Upper record, coil antenna at maximum; lower record, vertical antenna.

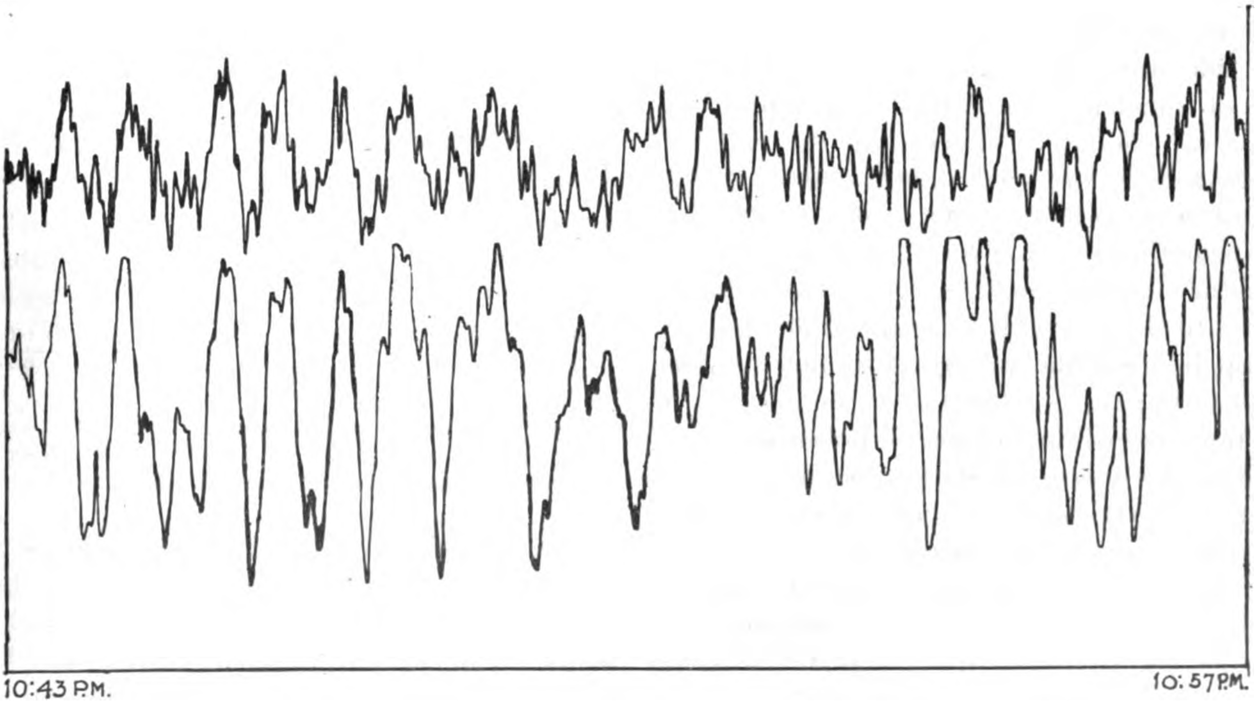

FIG. 5.

WTFF (1480 kc), Mt Vernon Hills, Va., received Kensington, Md., 31 km., March 19, 1928. Upper record, vertical antenna; lower record, coil antenna at maximum.

cliffe on the other hand, found the two records varying together when the ground ray was not suppressed (24).

A possible explanation of this anomaly may be reached by the process of elimination. Making the usual assumption that the indirect ray remains in the plane of the great circle connecting transmitter and receiver, the combined effect of ground and downcoming rays should be to cause similar changes in both vertical single-wire and coil antennas. The only exception would be when the atmospheric ray arrived with zero angle of incidence, in which case only the ground ray should be effective in the vertical antenna and the intensity should remain at the daylight level, while in the coil antenna the combined effect of the two rays should continue to produce fading changes. This explanation does not fit the data; it is a change of phase relationship between the two records, not a cessation of fading in one, that is to be accounted for. Rotation of the plane of polarization of the incident ray also should produce like effects in the two receiving systems; therefore, by itself, this offers no solution.

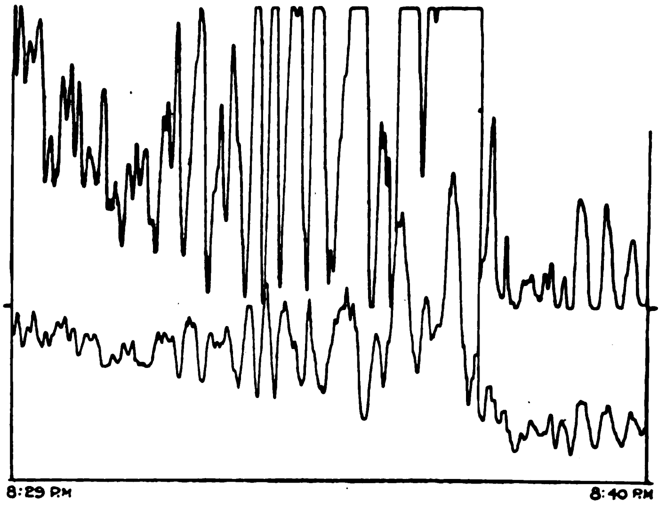

FIG. 6.

WTFF (1480 kc), Mt. Vernon Hills, Va., received at Kensengton, Md., 31 km., May 17, 1928. Upper record, coil antenna at maximum; lower record, vertical antenna.

The answer is presumably associated, directly or indirectly with the nearness of transmitting and receiving stations. For the distances concerned, 13 to 53 kilometers, it is perfectly possible to have direction shifts of the incident ray as great as 90°, due to irregularities in the refracting or reflecting upper atmosphere. This could account for changes on the vertical antenna not occurring on the coil antenna, but not for the considerable time lag between similar changes produced in the two receiving systems. If, however, there should be a lateral direction shift combined with a rotation of the plane of polarization for the dowcoming ray, we should expect just such differences in the pairs of records as appear. Suppose, for purposes of illustration, that the reflected ray is arriving with constant intensity and normally polarized. If, now, the lateral angle of arrival shifts until it becomes 90° the signal intensity in the vertical antenna will remain constant while that in the coil antenna will decrease to a minimum, in fact, to zero, if there should be no ground wave present.

If, next, the plane of polarization rotates, the vertical component of the electric field will decrease until, with the electric field horizontal, the ray ceases to produce a current in the vertical antenna. Simultaneously, the component of the magnetic field in the vertical plane will have increased from zero to a maximum, thereby producing maximum current in the coil antenna for the given angle of incidence. Thus we have similar fading characteristics 180° out of phase in the two antennas. If the direction of arrival of the incident ray gradually returns

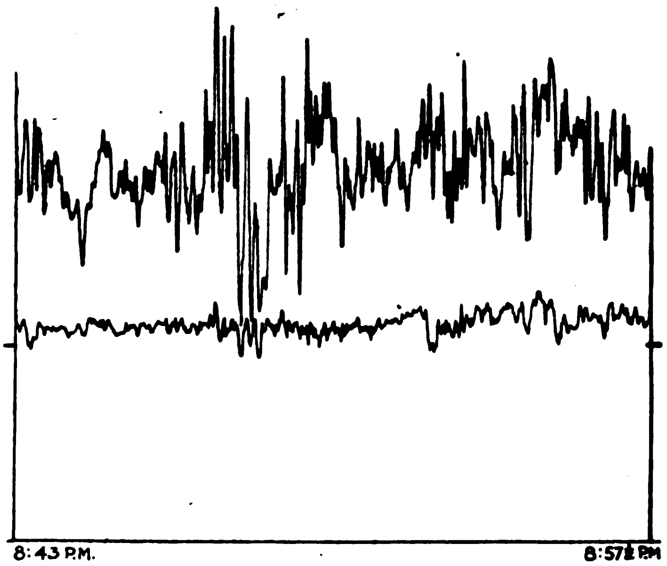

FIG. 7.

WMAL (1240 kc), Washington, D. C., received at Kensington, Md., 13 km., April 2, 1928. Upper record, coil antenna at maximum; lower record, vertical antenna.

to the plane of the maximum coil antenna and the rotation of the plane of polarization continues, whether at regular or irregular speed, the phase difference between the two records will gradually decrease until it disappears. With the direction shifts more or less erratic we should have just the sort of changing phase relations shown on the records of figures 4 to 7; and if rotation ceased we should again find the two records running in phase, as in the early part of figure 5 or the latter part of figure 6.

The question whether the direction shifts necessary to the above explanation actually exist requires proof. Bearings on these stations were taken at night by means of a coil antenna, and revealed apparent direction shifts which were considerable. An actual test, however, can only be made with an antenna of the Adcock type ([25]) if true directions of arrival of the reflected ray are to be found. Such a test awaits the construction of further apparatus.

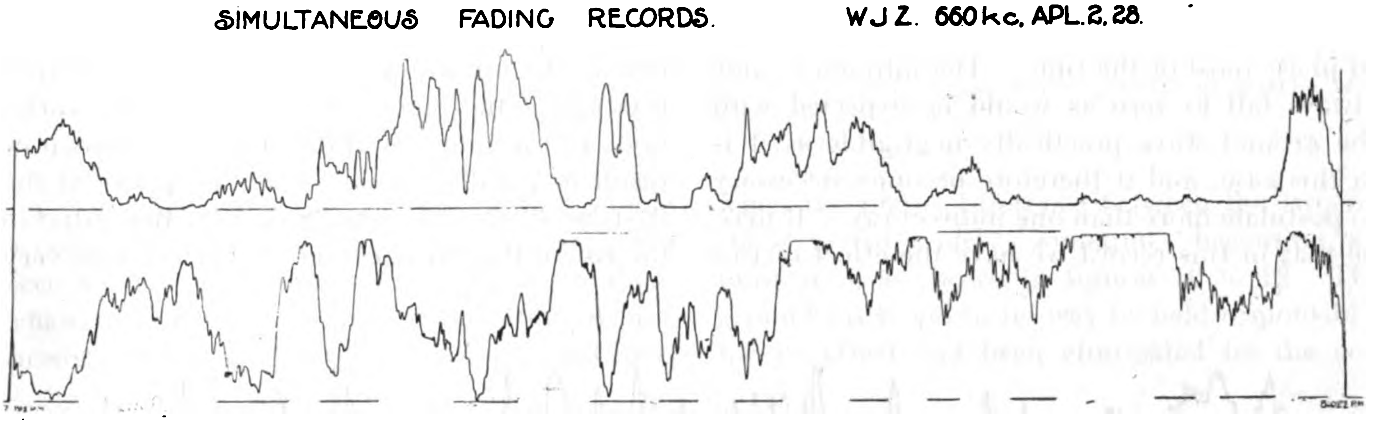

Fig. 8.

WJZ (660 kc), Boundbrook, N. J., received at Kensington, Md., 300 km., April 2, 1928. Upper record, coil antenna at maximum; lower record, coil antenna at minimum position.

Interference between the indirect reception and the ground ray is evidenced on many of the records made with the coil antenna in maximum position, and to a lesser degree by those made with the vertical antenna. Wherever the intensity of one of these records falls below the daylight level the indirect reception must be to some extent out of phase with the waves arriving along the surface of the earth. Figures 4 to 7 give clear indications of this. Note particularly that even for stations as near as 13 kilometers from the observing point the intensity of the downcoming ray is sometimes nearly as great as that of the ground wave, so that when the two are opposite in phase the intensity of the ground ray is largely neutralized and the record drops almost to zero. Presumably in these same records the peaks are due to the addition of the reception by direct and indirect paths. It will later be shown, however, that peaks may be due to other causes, whether the ground wave be present or not.

Simultaneous Fading Records with Two Coil Antennas, at Maximum and Minimum Positions, Respectively. — The second method of investigation was by simultaneous fading records of the same transmission as received by two coil antennas, one in the maximum, and the other in the minimum position. The purpose of this arrangement was to secure some data as to fading caused by rotation of the plane of polarization of the indirect ray; for such a phenomenon, if present, should cause an increase of intensity in either coil antenna to be accompanied by a decrease in the other. So far as possible the minimum bearing was found for the various stations during daylight when there was no evidence of an indirect ray, and these bearings checked satisfactorily on different days. For the more distant stations, however, no ground wave could be received in daylight and it was necessary to trust to approximate bearings, which were sufficient for the project in hand.

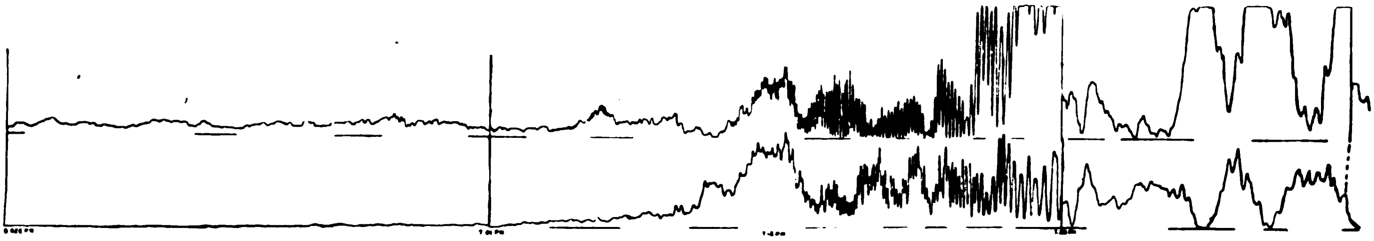

Fig. 9.

WJZ (660 kc), Boundbrook, N. J., received at Kensington, Md., April 5, 1928. Upper record, coil antenna at maximum; lower record, coil antenna at minimum.

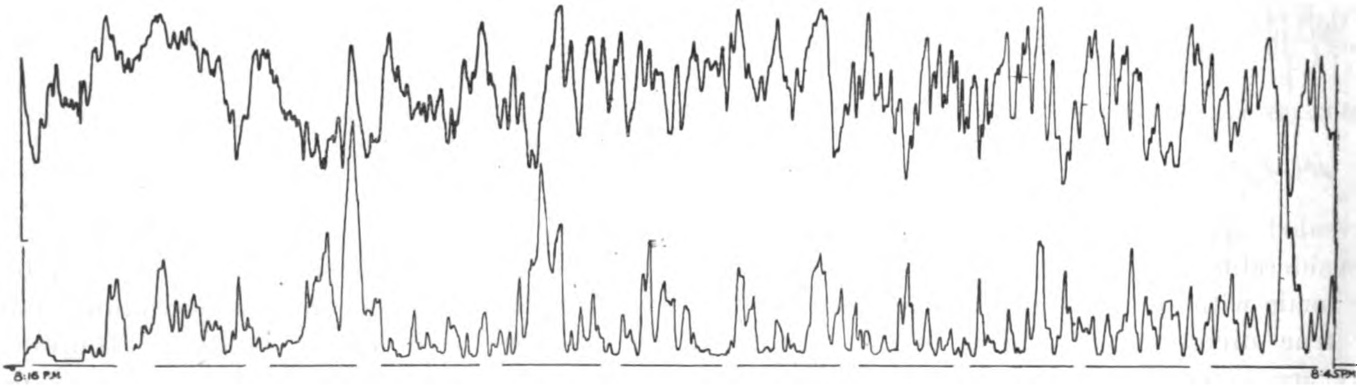

Fig. 10.

WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., April 17, 1928. Upper record, coil antenna at maximum; lower record, coil antenna at minimum.

The data secured offers considerable striking evidence of the above mentioned phenomenon. Figure 8 is a typical section cut from a pair of simultaneous records. Here it is possible to see at a glance that the two are practically 180° out of phase most of the time. The minima do not always fall to zero as would be expected with the ground wave practically negligible as it is in this case, and it therefore becomes necessary to postulate more than one indirect ray. It may be that in this record we have the effect of two rays rotating at different speeds so that their minima do not synchronize most of the time. Interference between the two is also probably present but the effect cannot be isolated in the record. Figure 9 is another record made on reception from the same station as figure 8, and is typical of what occurs during the sunset period. Up until a half hour after sunset the weak ray from the upper atmosphere appears to remain normally polarized and so produces intensity changes only in the maximum coil, possibly through a combination of interference effects and varying absorption. Then gradually evidence appears that a downcoming ray somewhat abnormally polarized is producing a current in the minimum coil. Even with no further rotation of the plane of polarization any variations in the intensity of the indirect ray may now result in parallel changes such as appear in the first large intensity peak at 7:12. Here, due to the rise of the ionized layer, and probably to very abnormal polarization, the intensity in the minimum coil is practically the same as in the maximum. From this peak on, nearly to the end of the record, the average trend of the maxima coil antenna record is 180° out of phase with the minimum, indicating that the rotary motion of the ray has gotten under way. Starting at about 7:04 P. M. on this same record there is a superposed rapid variation having a period of from 3 to 30 seconds. This characteristic is also exactly out of phase on the two records and so suggestive of a second and relatively much weaker ray with plane of polarization rotating rapidly. Assuming the polarization to be plane a complete rotation would have to occur in six seconds to produce the most rapid of these changes, whereas elliptical polarization would produce the same effect by a twelve-second rotation. With elliptical polarization, however, alternate peaks should be of differing magnitude.

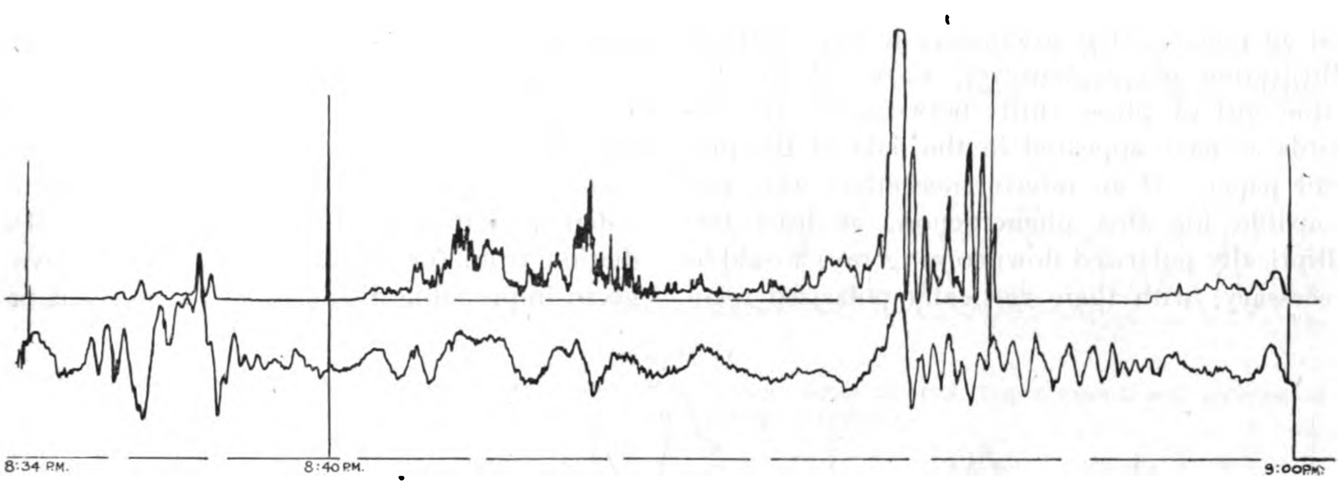

FIG. 11.
WMAL (1240 kc), Washington, D. C., received at Kensington, Md., 13 km., June 5, 1928. Upper record, coil antenna at minimum; lower record, coil antenna at maximum.

While this data and much more seemed to be consistent with a rotating plane of polarization in the indirect reception, there were times when the phase difference between the two records varied widely, sometimes becoming almost zero, as shown in figures 10 to 12. The ground ray could in no way be held responsible, for its effect had been eliminated by the coil

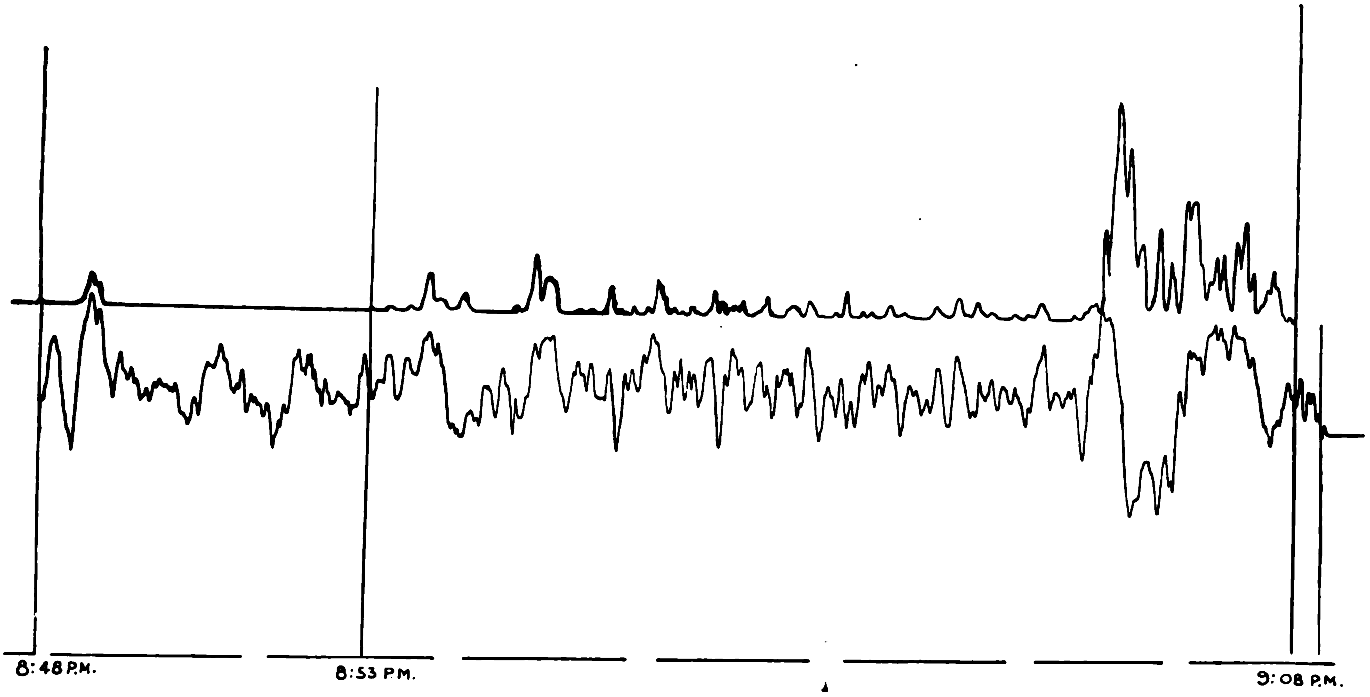

FIG. 12.
WMAL (1240 kc), Washington, D. C., received at Kensington, Md., 13 km., June 6, 1928. Upper record, coil antenna at minimum; lower record, coil antenna at maximum.

antenna in minimum position, and yet variations in one antenna led or lagged behind similar variations in the other. In a recent article Eckersley (^{22}) reports that records of high frequency transmissions received simultaneously with vertical and horizontal antennas are opposite in phase. It is interesting to note that the illustration given, however, shows clearly the same sort of phase shifts between the two records as have appeared in the data of the present paper. If an interference effect were responsible for this phenomenon, at least two elliptically polarized downcoming rays would be necessary, with their vertically polarized components having a different phase relationship from that of their horizontally polarized components.

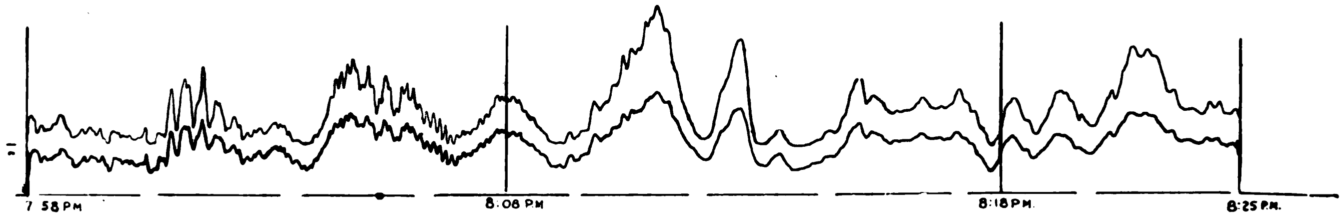

FIG. 13.

WJZ (660 kc), Boundbrook, N. J., received at Kensington, Md., 300 km., June 6, 1928. Both records made on coils at maximum.

A more plausible explanation is that suggested for similar out-of-phase relations which occurred in the records made simultaneously on coil and vertical-wire antennas. If an atmospheric ray with rotating plane of polarization were arriving with an angle of incidence of nearly 90° and the plane of its arrival should gradually shift from 0° to 45° with the maximum position of the coil antenna the records made simultaneously by coil antennas in maximum and minimum positions would gradually shift from the 180° out-of-phase relationship to a nearly in-phase relationship. If the angle of incidence were considerably less than 90° similar changes in phase relationships would take place as the direction of arrival shifted to the 45° position, except that the two records would never come completely into phase. As the angle of incidence decreased still further the two records would be more and more out of phase. If the indirect rays always arrive by means of a single reflection the angle of incidence at the receiving and would increase with the distance between transmitting and receiving points and a direction shift of given angle would produce a greater phase shift in the pair of fading records for a distant than in the pair for a nearer station because the incident ray for the former is more nearly horizontal. On the other hand, it should be possible for the ray from a nearer station to arrive at larger angles with the plane of the coil antenna in maximum position since lateral radiation from the distant station would have to go to improbable distances to be reflected back at large angles. Very distant transmissions, furthermore, would presumably be received almost entirely in the great circle plane passing through transmitting and receiving stations. In the case of possible multiple reflections of the same ray or of an inverted U-shaped path the situation would be altogether different. Further measurements of the apparent effective height of the ionized region according to the method of Appleton and Ratcliffe, providing a sufficient variety of distances be covered, may give some useful information, for the method should prove most accurate and consistent for the distant stations if there are actual lateral reflections present.

As a partial check of the possible shifts in the direction of arrival of the indirect ray, observations were made simultaneously with three receiving systems utilizing, respectively, a coil antenna in maximum position, a second in the minimum or perpendicular plane, and a third in a vertical plane at an angle of 45° with the other two. Comparisons were made vocally by the three observers as changes occurred in the indicating galvanometers, since the third recorder for securing graphic records was lacking. Observing was done at a time when the phase relation between changes in the perpendicular coils was varying The triple observations showed that for considerable periods the variations in the 45° coil were more nearly in phase with those in the coil at maximum, at times more nearly in phase with changes in the coil at minimum position, and for other periods considerably out of phase with both. Such effects do not prove direction shifts to exist but are similar to what would be expected if such shifts were real.

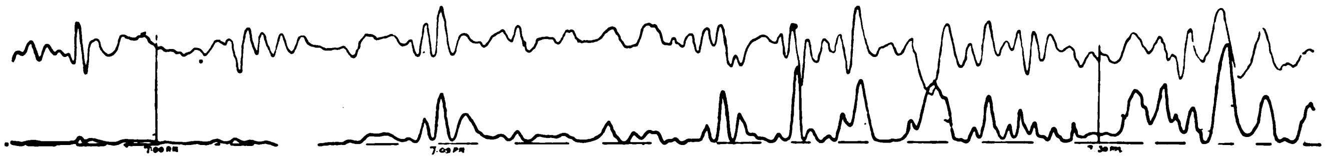

FIG. 14.
WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., April 27, 1928. Upper record, coil antenna at maximum; lower record, barrage minimum.

Figure 13 is typical of records taken from time to time to make sure that differences in simultaneous records were not due to the separation between receiving antennas. In all of these records made with similar antenna systems the simultaneous records showed that every variation, small and large, was in phase on the two records.

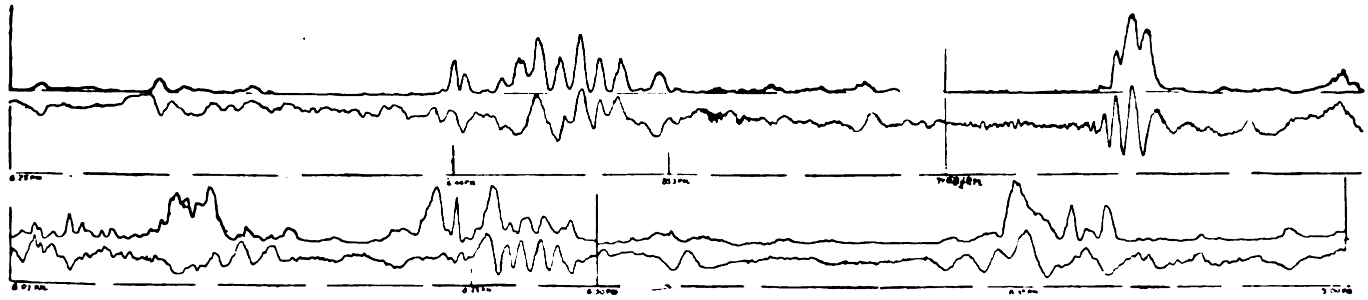

FIG. 15.
WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., April 26, 1928. Upper record, barrage minimum; lower record, coil antenna at maximum.

Simultaneous Fading Records Made with Barrage Antenna and with Vertical Single-Wire or Coil Antennas. — Using the barrage combination of antennas to eliminate effects due to the ground wave, and the coil antenna in the maximum position to receive both ground and indirect rays, it was hoped that differences in records would indicate the amount of fading due to interference between these two rays. With the indirect ray remaining in the plane of the great circle connecting the two stations, changes other than those due to interference should have similar effects on the two receiving systems, though the magnitude of changes should differ.

Figures 14 and 15 show typical pairs of records. The earlier portion of the records of figure 14 occurs during sunset before the angle of incidence of the indirect ray has decreased sufficiently to allow more than a feeble horizontal component of the electric field. Consequently the intensity changes are quite feeble at first but increase as the ionization retreats upward. During the first half of the records the intensity variations are in phase in the two antenna systems, indicating that these changes are produced farther back in the transmission path. The later portions of the records, however, show some changes in one antenna to be lagging similar changes in the other. Figure 15 shows similar lagging effects at approximately 6:44 to 6:53, 8:25 to 8:30 and 8:47 P. M. At other times this pair of records is usually in phase or 180° out. The latter condition is well explained by the fact that as the horizontal electrical component of the indirect ray increases, as shown by the barrage record, the vertical component presumably increases also, and being out of phase with the ground ray, whether partially or completely at these particular times, causes a reduction of intensity in the coil antenna set at maximum position.

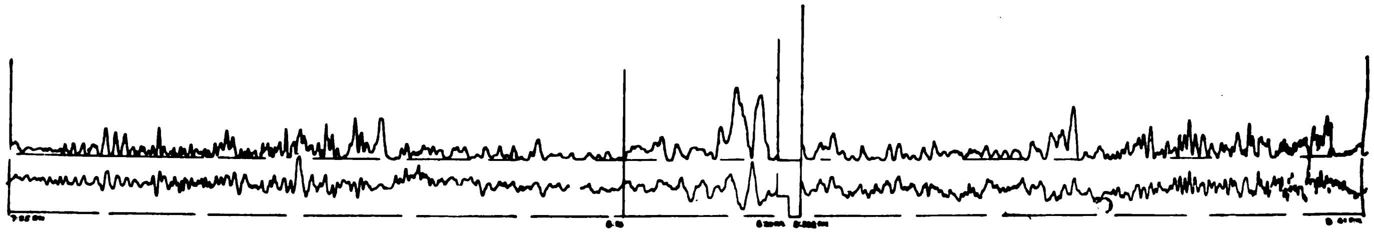

FIG. 16.

WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., July 6, 1928. Upper record, barrage minimum; lower record, vertical antenna.

Figure 16 shows records made by a method similar to that last described except that a vertical single-wire antenna was substituted for the coil in maximum position. This method was used by Appleton and Ratcliffe (23). Though the fading is more rapid in figure 16, the phase relations between the records are similar to those of figures 14 and 15, with less positive indications of the lagging effect because of the rapidity of variations. This effect does appear on a record (23) shown by Appleton and Ratcliffe, however. The explanation given by them, that the difference in records is due to the interference between indirect and ground rays which can affect only one of the two receiving systems, is a possible one for all of these pairs of records. Two facts, however, cast some question upon this an a complete solution : 1° it is doubtful if interference can account for the slight phase displacements in similar portions of the two records as it may well account for the 180° out-of-phase relationships; 2° similar varying phase relationships appear in records already discussed, those made with the vertical antenna and with the coil antenna in maximum position with no elimination of the ground ray. Shifts in the direction of arrival of the downcoming ray would make the latter more effective on the vertical antenna portion of the barrage system than on either coil.

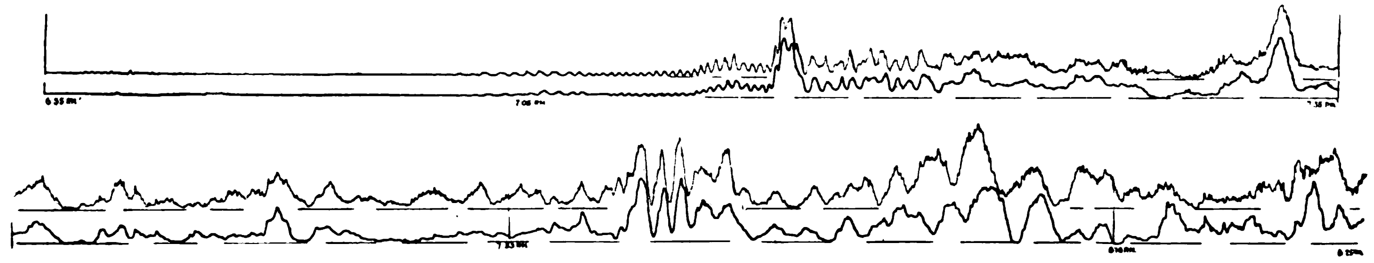

FIG. 17.

WBAL (1050 kc), Baltimore, Md., received at Kensington, Md., 50 km., March 30, 1928. Upper record, coil antenna at minimum; lower record, barrage minimum.

If rotating plane of polarization be combined with a direction shift in this ray the phase relationships appearing in the pairs of simultaneous records become explicable. Three simultaneous records utilizing the vertical antenna, the barrage system, and the coil antenna, should throw further light on the problem.

Again, the barrage system was used simultaneously with the coil antenna in minimum position. This provided a method of eliminating results of the ground wave from both coils so that remaining effects should be due to indirect reception only and to the angles which the coils made with that indirect reception. The effect of the entire vertical electric component of this ray should, of course, be eliminated in the barrage system. Figure 17 shows the type of record secured on transmission during the sunset period from a station only 53 km distant. The changes, both large and small, are very nearly of the same magnitude and the larger variations are usually in phase on the two records. The phase relationships of the smaller periodic variations change considerably but are most often 180° out. In other words, this pair of records has much the same characteristics as appeared on the WJZ records, made with coils in maximum and minimum positions, in which the effect of the ground wave was practically absent because of great attenuation due to distance. There is in the early part of the records a superposed periodic variation suggestive of an indirect ray of small intensity with rotating plane of polarization and some shift in the lateral angle of arrival to cause changing phase relationships in the two fading records. The major variations would appear to be caused by a much stronger indirect ray of varying intensity with its plane of polarization unchanging at first but later rotating slowly, thus causing changes in one record to lag behind similar changes in the other. This rotation effect was not found in the records made by Appleton and Ratcliffe (²⁶) with similar antennas. The intensity variations shown by their simultaneous records were so largely in phase that most of the fading could be explained by intensity variations occurring at some distance from the receiving antennas.

Short Period Fading. — The rapid periodic fading previously mentioned and illustrated in figures 9 and 17 should have some significance since there is a considerable degree of regularity in its appearance, at least in reception from the two stations upon which observations have been most consistently made. During the cooperative investigation of fading (⁸) conducted by the Bureau of Standards in 1925 this same phenomenon was noted, though less consistently, in observations made at several different localities on transmissions from WGY (790 kc), Schenectady, N. Y. In the earlier case the phenomenon occurred for a few days at the spring equinox and was not found again. The newer cases were first noted at the same season but have continued for several months with very few exceptions whenever records were made. On the WJZ records this type of fading starts from 15 to 30 minutes after the Washington sunset and lasts in the vicinity of a half hour. On the WBAL records, which were made much less frequently, the start is likely to be practically at sunset, though there is some variation both ways.

The explanation of this phenomenon suggested in the earlier paper as an interference effect between ground and reflected rays is now proved unsatisfactory by the fact that this periodic fading is present even when the ground ray is absent. As previously stated, the fact that such fading is out of phase on records made with coils at maximum and minimum positions, respectively, makes any interference explanation difficult and suggests a relatively weak indirect ray with rapid rotation of its plane of polarization. No explanation is given at this time for the rotation itself.

Conclusions.

1. Considerable fading is caused by the fact that the indirect ray from a radio broadcasting station undergoes variations of intensity before arriving at the receiving antenna. This is proved by the fact that at times similar intensity changes occur simultaneously in coil antennas at maximum and minimum positions as well as in barrage antenna and coil at minimum.

2. Much evidence of fading caused by interference between ground and indirect rays is found in records of reception from transmitting stations sufficiently near to produce a ground wave at the receiving point. The night-time intensity is often less than the day-time intensity which is due to the constant ground ray. The out-of-phase indirect ray often neutralizes the effect ot the ground ray partially and sometimes completely, even for short transmission paths.

3. Direction shifts are apparently necessary to the explanation of phase displacements of

less than 180° between otherwise similar records made simultaneously : 1° with coil antenna at maximum and with vertical single-wire antenna; 2° with coil antenna at maximum and with barrage antenna; 3° with barrage and vertical single-wire antennas; 4° with coil antennas at maximum and minimum position; 5° with barrage and with coil antenna at minimum. Oscillographic studies and direction observations with an antenna of the Adcock type to eliminate effects of rotation of plane of polarization, as well as records made simultaneously with more than two types of receiving antennas are desirable to verify direction shift indications.

4. No proof of fading caused by fluctuating height of the ionized layer is found, but evidence of refraction of the indirect ray from a rising layer is found in the fact that the signal intensity in the coil antenna at minimum position starts at zero in daylight and gradually increases during sunset.

5. Rotation of plane of polarization of radiation refracted from the upper atmosphere is shown to be the cause of much fading, particularly, though by no means wholly, during the sunset period. The 180° out-of-phase relationship between records made simultaneously with coil antennas in maximum and minimum positions seems to demand this explanation. The cause of such rotation is not explained.

6. Reflections arriving by multiple paths are evidenced in records showing a periodic type of fading superposed on the main intensity variations and yet 180° out of phase on simultaneous records made with coil antennas in maximum and minimum positions. This fact makes the calculation of the effective height of the ionized layer by means of the sine of the angle of incidence, as determined by the method of Appleton and Ratcliffe (27), somewhat doubtful, especially when measuring on other than distant stations.

7. The rapid periodic type of fading noted in a previous paper as occurring in signals from one station during the sunset period has been found to be quite common in the reception from two other stations. The newer data point toward rotation of plane of polarization rather than interference as the cause.

As stated in the introduction this investigation is far from complete. It is planned to make similar measurements over a much longer period of time to observe possible seasonal effects; to make simultaneous measurements by more than two receiving systems over a wider range of frequencies;to compare results of transmissions perpendicular to the earth's magnetic field with those parallel to it; to make direction observations and oscillographic observations simultaneously with the fading records; to make more quantitative measurements of these observations and compare calculated heights of the refracting layer, as determined by the angle of incidence method, on transmissions involving a wide range of distances, in order to note whether there is greater consistency in measurements on the more distant stations.

Acknowledgements.

Special acknowledgement is made of the assistance of Mr. H. S. Shaw of Exeter, N. H., whose contribution of the salary of a research associate made possible the carrying on of this work at the Bureau of Standards.

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THE PRESENT STATE OF BRITISH RESEARCH ON ATMOSPHERICS

by R. A. WATSON WATT.

1. Introductory. — In order to define the scope and outlook of the present report, it should be said that it is a summary report of progress in a study of the morphology and etiology of atmospherics in themselves rather than in a study of the pathology of radio communications. It will mainly be concerned with the shape and size of atmospherics, the circumstances of their origin, and the incidents of their travel from the source to the receiver.

2. Waveform of Atmospherics. — An electrical discharge in the atmosphere consists essentially in the destruction of an electrical moment measured by the product of a quantity of electricity and the height through which it is moved. The electric field produced at a distance r, in free space, by the destruction of a moment M is given by the equation.

$$E = \frac{1}{r^3} M + \frac{1}{cr^2} \frac{dM}{dt} + \frac{1}{c^2 r} \frac{d^2 M}{dt^2}.$$

If the time curve of destruction of moment is of the form shown in figure 1*a*, the rate of destruction is measured by the first differential curve 1*b* the net area of which will represent the total moment destroyed and which will reach the zero line at the times of beginning and end of flow of current. The second differential curve 1*c* will be of zero net area, since an unbalanced area would represent continued flow of current.

Methods are available, using the cathode ray oscillograph, from which may be inferred the net change of field corresponding to the first (or electrostatic) term in the field equation, the only term which does not return to zero on the termination of the discharge. The same apparatus enables the remaining parts of the field change to be delineated, and in general the second (or induction) term will be so small in relation to either the first or the third (radiation) term that the measurements made on the oscillograph may be taken as representing term (1) or term (3) alone. A very slight modification in the method of observation enables us to measure the rate of change of field $\frac{dE}{dt}$.

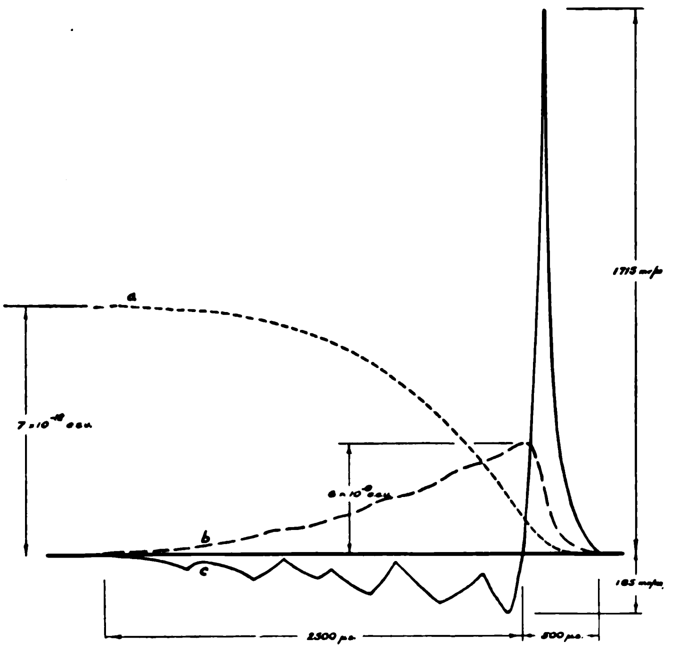

FIG. 1.

With these elementary considerations in mind, we may turn to the examination of forms of atmospherics delineated by these means. Dealing with a sample group of 8000 atmospherics delineated by an eye and hand method in South East England in autumn, figure 2 shows scale drawings of the most frequently occurring classes and indicates their percentage frequency. Figures 3 and 4 show on the same scale, the forms occupying the principal places in sample groups from Khartoum for the month of April and from Western Australia in March. It will be noted that in all cases there is a clear majority of sensibly aperiodic forms, i.e. forms in which no reversal of voltage could be measured in the receiving aerial, or more

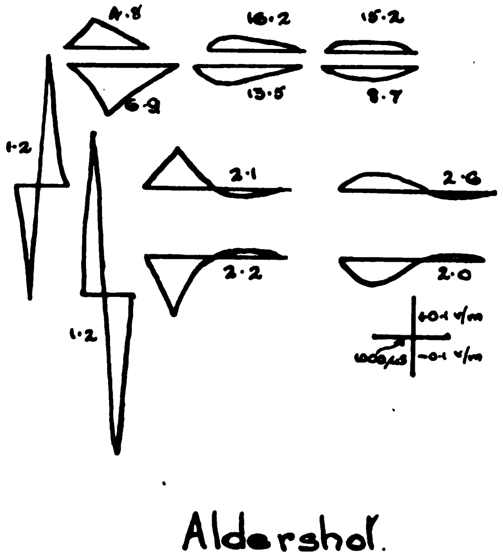

FIG. 2.

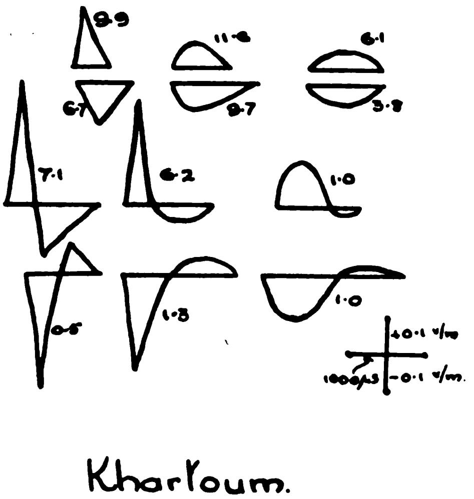

FIG. 3.

strictly forms in which no reverse field reaching 4 millivolts per metre occurred within a period comparable with some small multiple of the time occupied by the field change as delineated. We do not yet understand the mechanism by which these aperiodic forms have been derived, whether by a wide separation in time between the period of strong acceleration and that of deceleration in the original discharge, or by selective dissipation. There are many significant numerical relations between the magnitudes of the mean aperiodic and the mean quasi-periodic disturbance which would appear to point to incidents of propagation rather than to peculiarities at the source as accounting for the high production of sensibly aperiodic forms. Thus for example Table I (*) shows the relation between the field strengths and durations of the main aperiodic forms and of the corresponding shapes when these occur as parts of quasi-periodic disturbance. This table helps to dispose of the suggestion, superficially attractive, that the aperiodic discharges may represent the induction term.

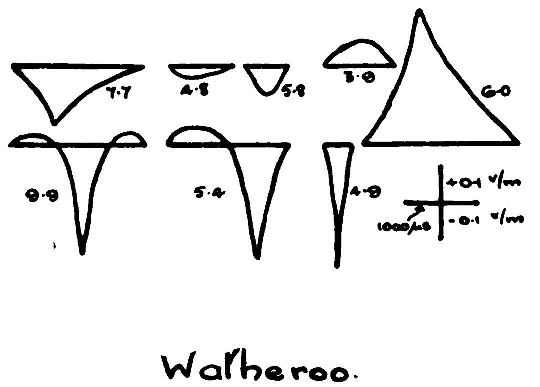

FIG. 4.

In cases where the radiation forms from visible lightning discharges at comparatively small distances have been drawn, the net area does not differ very widely from zero, and the difference may be explained by inaccuracies in the eye and hand method. It is perhaps permissible to infer that strictly accurate delineation would have shown equal areas on the two sides of the base line, in agreement with the starting and stopping of the discharge current within the time of delineation. By a graphical double integration of a form delineated in England for lightning 300 km. distant, the electrical moment destroyed is found to correspond very closely to that (3×10^{16} e.s.u. cm.) measured by Mr. C. T. R. Wilson in the cases of measurement on lightning at very short ranges. Table II shows the results of the process as applied to fields from lightning discharges 100 km. 300 and 600 km. away. Figure 1*c* is an exact redrawing of an atmospheric actually delineated at Khartoum and radiated from lightning some 100 km. distant. It is of zero net area, and the double integration represented in figures 1*b* and 1*a* leads to the value of 6×10^{16} e. s. u. cms. for the moment destroyed in this tropical lightning discharge.

Although the data is quite inadequate for a general survey of the geographical and seasonal variations of the characteristic waveforms, Table III indicates that the mean peak field strengths fall off with increasing latitude, while the mean durations of individual atmospherics normally increase with latitude, so that the mean rate of change of field, on which interferent power largely depends, increases very steeply with decrease of latitude. There is a suggestion in Table III that the negative aperiodic form is more universal in character than are any of the other main classes. It will be seen from the data shown that the durations and periodicities of the fundamental forms are not of the same order of magnitude as the periodicities used in wireless signalling. Some doubt has been expressed as to whether such relatively slow field changes would account for the interference actually experienced in wireless signalling. There is little doubt that the steep initial slopes delineated would suffice to produce considerable e.m.fs. in radio receivers, but that there is a further explanation of the interferent properties of atmospherics may be shown by the examples of fine structure superposed on the fundamental waveforms drawn, particularly in the tropics and in the hours of darkness. In two cases noted at random this fine structure actually had a 4000 metre wavelength and a peak field strength of 10 millivolts per metre,

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(*) Page 129.

i.e. some 4000 times as great as would be required for signalling by artificially generated waves of the same frequency. Further, the method already referred to for the delineation of curves of rate of change of field will show the short period components on an enhanced scale and in fact even in Great Britain this enhancement of fine structure is sufficient to make the $\frac{dE}{dt}$ oscillogram too complex for delineation.

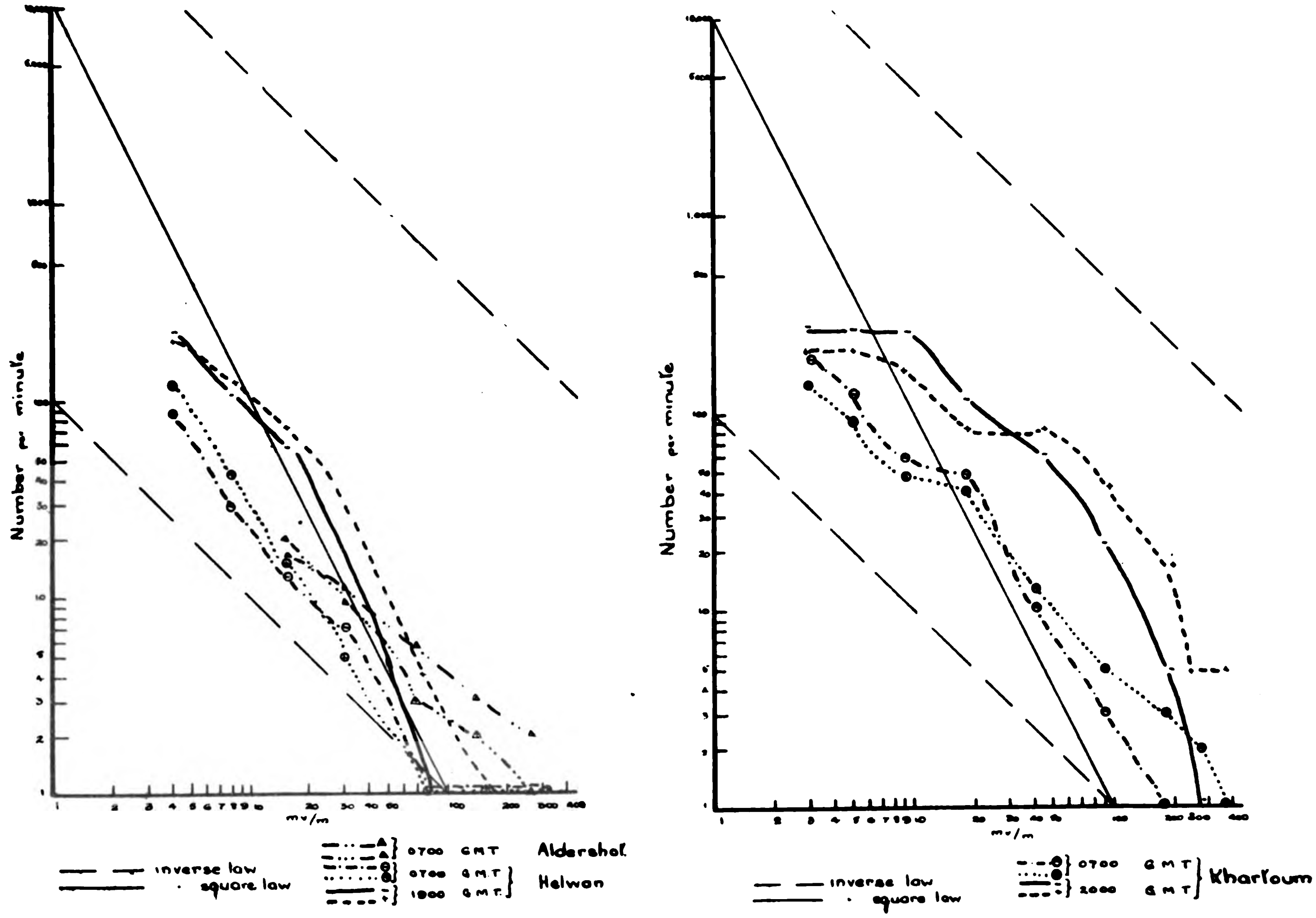

FIG. 5.

No of atmospherics per minute of field strengths shown. Aldershot, Helwan, Khartoum.

3. Numerical Incidence of Atmospherics. — Passing from characteristics of form to the investigation of the temporal incidence of atmospherics of various strengths, we find that the circuits employed for delineation of form are also convenient for the examination, without the use of a time base to open out the pattern, of the relative frequency of occurence of peak field strengths between specified limits. Figure 5 shows the numbers of atmospherics per minute which passed amplitude limits up to 500 millivolts per metre at Aldershot, Helwan and Khartoum; the curves are drawn on logarithmic scales in respect both of field strength and number per unit time, and while it is at once evident that no simple law will fully express the distribution, complicated as it is by conditions of light and dark, yet an adequate first approximation is given by a law of the form $N E^2 =$ constant, K.

An interesting feature of these distribution curves is that while small negative peaks are numerically predominant, in both morning and evening hours; yet amongst the stronger peaks exceeding 30 millivolts per metre, there is a clear preponderance of positives. This is only one of a group of differences peculiar to field changes of different instantaneous signs. The direct counting process breaks down somewhere between one millivolt per metre and 5 millivolts per metre because the frequency of occurence of such discharges is too high for the counting powers of the observer. It is however, a matter of very considerable interest to determine the relative frequency of incidence of peaks so small as to be just over the limit of perception in the oscillographic method used; this problem was first attacked in the course of a cruise in tropical waters during which I had the privilege of collaborating with scientific officiers of H. M. Signal School (Messrs. C. E. Horton, M. A., and J. C. W. Drabble) in observations on atmospherics. The method employed was to ensure that the fluorescent spot of the oscillograph did not retrace the same path within the path of persistence of vision. This ensured that all phenomena seen on any portion of the figure actually occured within the corresponding time interval. The diagram figure 6 shows the number of peaks per second passing the threshold of measurability in several 24-hour counts made in the Red Sea in the month of November. It must be confessed that these counts at once surprised and alarmed the investigators, but they are consistent with a large number of counts carried out by the same method at land stations. For example, at Helwan the average number of individual peaks passing the threshold of observation was approximately 100 per second at 8 hours G.C.T., 250 per second at 18 hours G.C.T. and 200 per second at 20 hours G.C.T. At Khartoum these numbers were almost always exceeded and counts of 1200 to 1500 peaks per second were not at all infrequent in dark hours. On one or

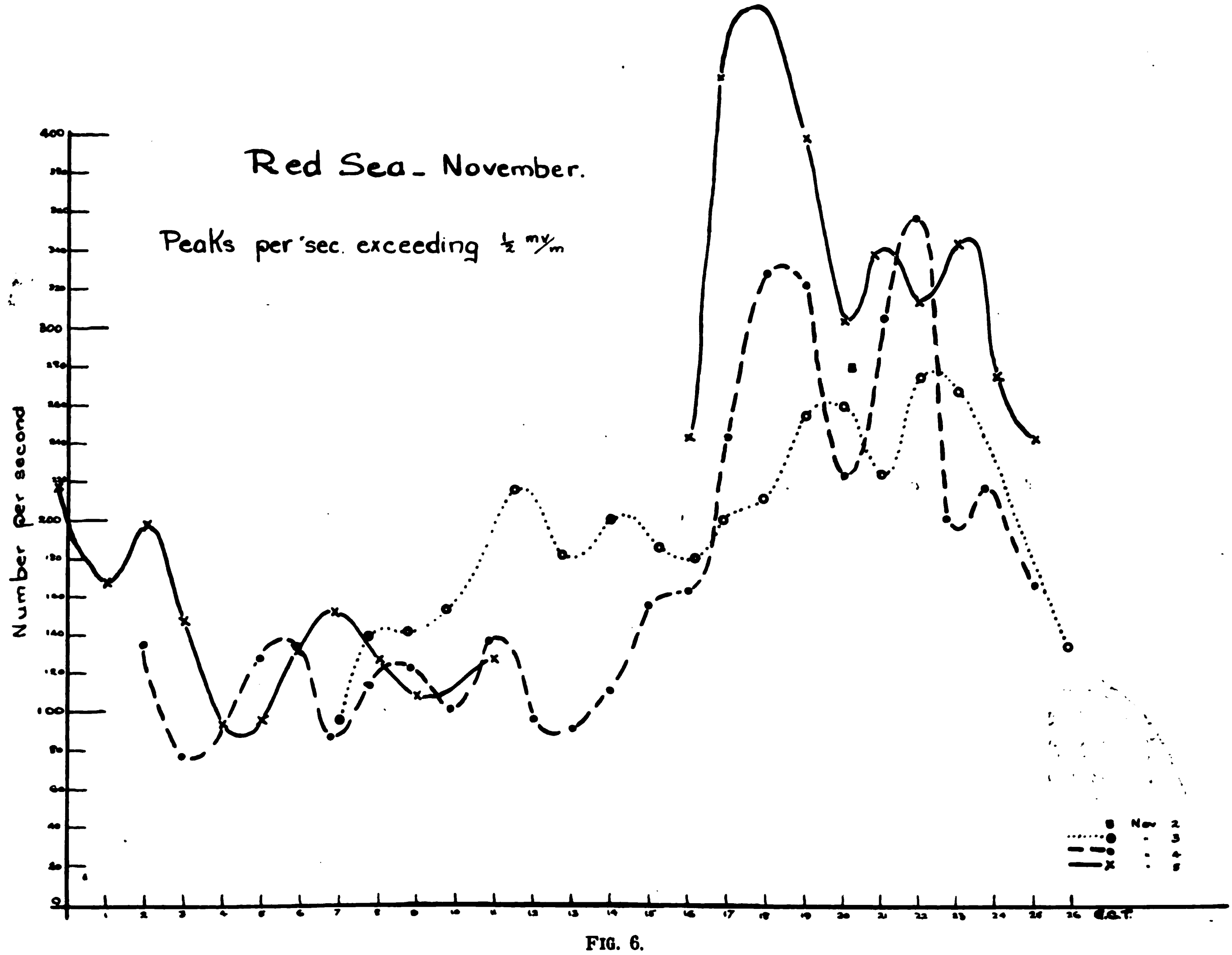

FIG. 6.

two occasions a count of the order of 3600 peaks was obtained and sounds of approximately this frequency were audible in the telephones. It is of further interest to note how these counts of small peaks fit into the approximate distribution law just enunciated. This is perhaps best shown by the indirect process of evaluating the detectable field strength as defined by those counts. It is found that if the constant K is determined by taking the numbers of atmospherics per minute passing the limits of 5 and 10 millivolts per metre, then the field strength E corresponding to a numerical frequency of 1200 per second is 1/4 of a millivolt per metre. This corresponds to an oscillographic deflection of 1/2 millimetre which would in fact just be detectable under average conditions of observation. The approximate inverse square law of numerical frequency of occurence may therefore be applied to radiation fields from half-a-volt to a quarter of a millivolt per metre. It may not be out of place to repeat that although this latter value has been called a small one, it is still of the order of 100 times the field strengths useful in radio communications.

Combination of the data of frequency of incidence and of the duration of individual forms will make it quite clear that in the dark hours in the tropics the occasion on which no considerable voltage from atmospherics exists in the aerial is a very rare occasion indeed, and it may be said that these observations give a vivid picture of the mechanism underlying the acute disturbance experienced in wireless signalling in the tropics, and they indicate quite clearly the reasons for the complete inadequacy of the anti-atmospheric devices which have been suggested in the past.

4. Directional Observations. — After some preliminary work had been carried out by aural methods on the mean direction from which the predominant stream of atmospherics reached particular stations at known times, pen-writing recorders were designed to supply more complete data of this nature. The general characteristics of the data from such a recorder installed at Aboukir, Egypt, show that throughout the year at approximately noon G. C. T. a predominant stream of atmospherics is arriving from nearly due South. This direction of arrival swings westwards throughout the afternoon and the swing is of the greatest amplitude near the autumnal equinox, least near the vernal equinox. This stream from westward diminishes in importance about 0500 G. C. T. when atmospherics arriving from the north-east begin to predominate, they in turn coming from directions more and more northerly until near noon when the stream from the south assumes first prominence. The amplitude of swing of this northerly stream is greatest near the vernal equinox, and in fact this stream is not traceable in the records near the autumnal equinox.

If simultaneous hourly mean values from all stations are plotted on a suitable graticule, a world map of travel of the principal sources of atmospherics results. (This map was exhibited at the session.) Each location is marked by a flag whose colour is characteristic of the season and which bears a flat-topped indicator whose colour shows the Greenwich Civil Time of the location, while the round topped indicator shows the local time. The most cursory inspection of the map suffices to demonstrate that the predominant source of atmospherics normally lies in a summer afternoon or evening, so that the cum-solar travel of the mean source of atmospherics, inferred from limited samples by various workers, is substantiated and amplified by the more complete recorder data here examined. The non-production of atmospherics over the Pacific and the prominence of mountainous regions as atmospheric producing areas are also clear from the chart, and the only point requiring explanation is the apparent contradiction of experience involved in the relative paucity of locations in Africa. This is due to the fact that the African sources are operative during the same periods as the European sources of similar longitude; despite the greater intensity of the African sources the proximity to home stations of the European sources cause these latter to predominate.

5. Individual Direction Finding. — Attention has been called elsewhere to the weakness of the older directional methods of observation in that they deal with average values only and may on occasion be actually misleading on account of the lumping in a statistical mean stream of two or more physical by separate streams. A method which was suggested so long ago as 1916 has recently been put into practical application for the determination of the direction of arrival of individual atmospherics at observing stations. The most complete test of this method which has yet been made was made possible by the kind collaboration of the Post Office Radio Station, Cupar, and operated by a method in which the observers at the two stations 500 km. apart were in direct telephonic communication with each other, so that almost complete certainty was attained as to the identity of the particular atmospheric whose direction of arrival was observed at the two ends of this base line. Figure 7 shows the distribution of places of origin of individual atmospherics on 29th June 1927. The bolder numerals superposed on the meteorological chart indicate the hours G.C.T. at which any one atmospheric was observed to proceed from the point at which the numeral occurs, the relative amplitude of the atmospheric is indicated on a scale of four steps by the nature of the numeral, an arabic numeral represents a small atmospheric, a small roman numeral one of medium amplitude, a large roman, one of large amplitude, and a large roman barré, an atmospheric of the largest readable amplitude, while symbols represent the incidence of thunderstorm phenomena as extracted from the daily weather reports of European meteorological institutes for the days in question. It will be seen that on the whole the picture of thunderstorm activity given by approximately 30 minutes total time of observation by two observers is of comparable adequacy to that given by the daily weather services. The figure includes lines showing the position of the polar front at two hours during the day. It will be seen that while the detail of the relation to the front is by no means clear, it is on the whole more definite than that shown by the thunderstorm data plotted.

A number of particularly interesting comparisons can be made between the locations of individual sources of atmospherics and thunderstorms reported in the admirably complete daily weather reports issued by meteorological institutes in the Soviet Union. For example a notably active source of atmospheric at 3 hours G.C.T. on July 1st 1927 around Tiflis corresponded to a thunderstorm which occurred at Tiflis during that night. From an examination in fourteen such cases of the maximum voltages produced in the cathode ray direction-finding circuits, which were tuned to 10 kilocycles, it may be deduced that the peak field strength of the 10-kilocycle component in atmospherics radiated from thunderstorms between 3000 and 5000 kilometres distant is approximately inversely proportional to the distance between source and observing station, with the additional condition that the product is subject to strong diurnal variation due to different attenuation in light and dark. It should be remarked that in a paper dealing with the waveform observations, an inverse square root law of diminution with distance was assumed and supported for the low frequency or fundamental waveforms. The present data, although too limited as a basis for the enunciation of a law, indicate that the law for the 10 kc. component probably lies between an inverse square root and an inverse first power law. A comparison of the products EK and $K\sqrt{E}$ against local time at the mid point of the path is shown in Table IV, which is satisfactory agreement with the known diurnal variation curves for long wave propagation. This crude comparison may be regarded as a hopeful first step in another of the outstanding major problems of the geophysical study of atmospherics, namely the examination of the relation between form of atmospheric (in the most general interpretation of form) and the circumstances of origin and propagation. In the absence of measurements of the wave forms, it is not possible to test the value of the moment destroyed, but on reasonable assumptions as to the ratio of the 10 kc. term to the fundamental, the order of magnitude of the moment agrees with that from short range measurements.

6. Intensity of Disturbance. — In a paper entitled « Directional Recording of Atmospherics » (*) will be found a figure showing the

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(*) *Jour. I. E. E.*, June 1926.

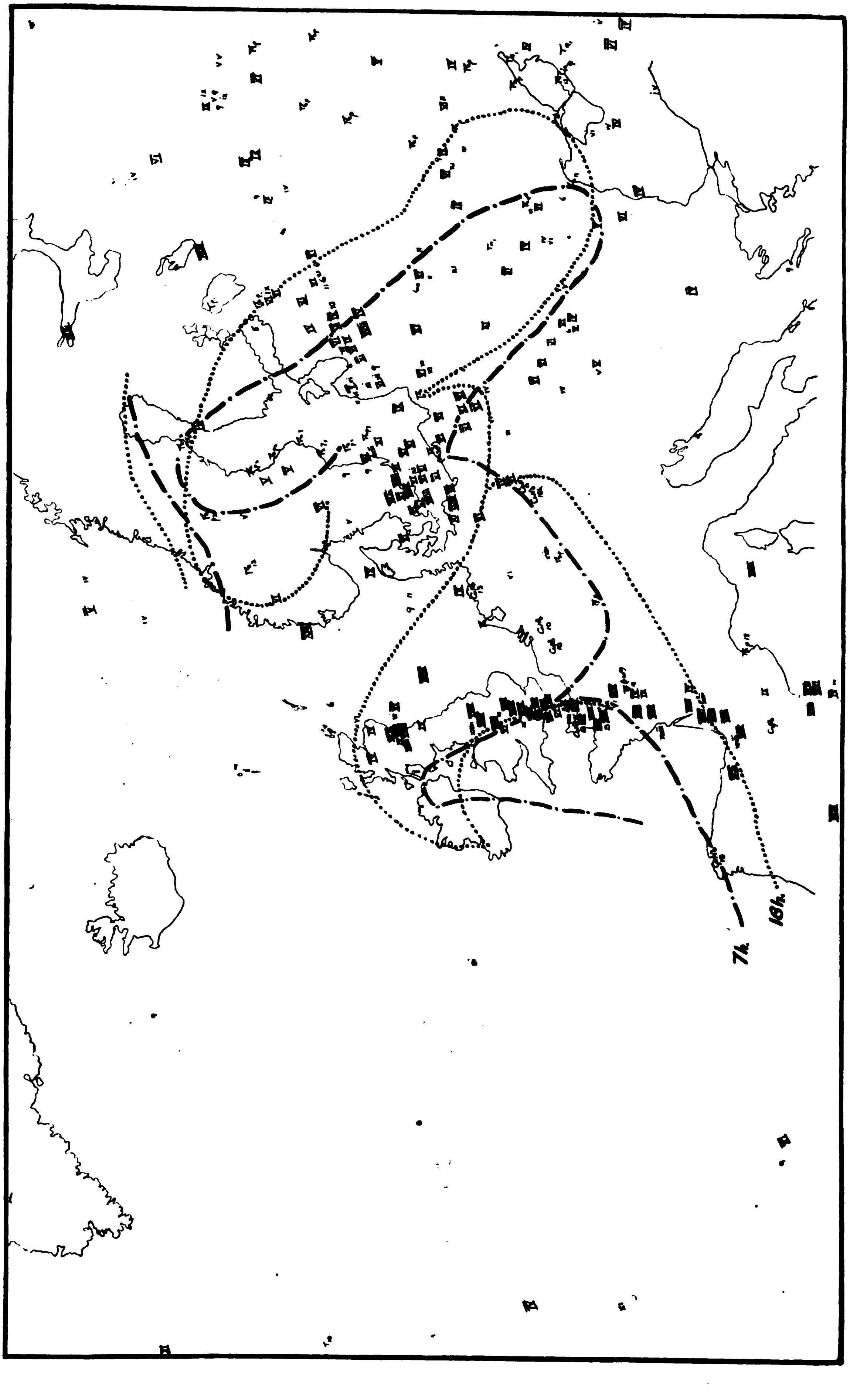

FIG. 7. — Atmospherics distribution 29th June 1927.

monthly mean curves of integrated intensity of disturbance at each hour of the day reduced from the records of the directional recorder at Aldershot for the years 1922 and 1924. The general nature of the seasonal variation is that throughout the year there is a principal maximum which occurs on the average about midnight and a principal minimum between 10 and 12 hours local time. The secondary maximum attains great prominence about 14 hours in summer alternoons but fails to appear in midwinter. In general this data may be interpreted as agreeing with the picture which represents atmospherics as coming in from great distances at all times, but with greatly increased facility during the hours of darkness, South American sources providing a maximum disturbance along the easy dark path round midnight G. C. T. The non-production of atmospherics over the Pacific strikingly shown by the world map of sources will account for the falling disturbance after midnight; the summer afternoon maximum is a symptom of the comparatively local disturbance represented in the world map by the closely clustered European sources during the afternoon hours of the European summer.

The principal maxima and minima shown by these monthly curves are closely related to the times of local sunrise and sunset, as is shown by figure 10 p. 83 of the paper referred to; the principal minimum of disturbance in April however, falls relatively late. This anomaly is found in the data from a considerable number of overseas stations. Fuller examination of the Aldershot curves will show that there are two minima approximately two hours apart, of which one or other predominates at different times of the year. It would appear then that oscillation between these two adjacent minima occurs also at the widely distributed stations for which partial data are available, but no explanation can at present be offered of this almost universal anomaly in a local time effect.

7. The Range of Atmospherics. — An acute divergence of opinion has for many years prevailed between different groups of investigators as to the average distance from its source at which an atmospheric may produce notable disturbance in the reception of radiotelegraphic signals. In particular Bellescize and Bureau in France have considered that the average atmospheric received at any station has probably originated within 100 km. On the other hand many observers British, German and American have concluded that on the average atmospherics are received from a radius of some thousands of kilometres. The computations referred to in the first section of this note were carried from the point already mentioned, at which it had been shown that the field from comparatively near sources were such as would be produced by the destruction of a moment equal to that measured by Mr. C. T. R. Wilson in the case of British lightning, and it was shown that the destruction of a moment of this magnitude within the time of duration of the average atmospheric would produce, at a distance of 3,000 km, a field strength which was in fact the one most frequently measured during the waveform observations, namely 60 millivolts per metre, and it was further shown that the comparatively insensitive methods used in the waveform work would detect the radiation from the destruction of such a moment at a distance over 10,000 km. An interesting direct test of the interferent range of atmospherics was organised by the Royal Meteorological Society. By the very kind cooperation of the British Broadcasting Corporation the committee responsible for the investigation were enabled to circulate to a group of observers distributed throughout Western Europe, North Africa and Madeira, typescripts of talks to be broadcast from the London and Daventry stations. At the actual time of the broadcast, the observers marked the syllables and spaces which were overlaid by atmospherics, and then returned the typescripts to a reduction centre. There tabular comparisons were made in which ordinates represent units of time identified by spoken syllables which were thus employed as time marks, while a column was allotted to each observer, an identification number being assigned to each for brevity. It was clear from these tabulations that we were dealing not with streams of atmospherics peculiar to each receiving station and coinciding only at random moments, but very clearly with conditions in which a single disturbance made itself felt over the greater part of the observing network at once. From the indications of the directional recorders and from observations made with the single cathode ray direction finder at Radio Research Station, it was possible to co-ordinate data as to position of source and the resulting disturbance in the following manner. The plotting of the recorder data indicated the position of the predominant source of atmospherics at the hour of observation. The cathode ray direction finder indicated that a particular atmospheric identified as to time of incidence by its effects on a specific syllable reached Radio Research Station along a great circle passing through the source indicated by the recorders, and thus very probably proceeded from that source. The records from the aural observers indicated that the syllable in question was disturbed at various stations, and that therefore again in all probability the atmospheric which produced this disturbance procee-

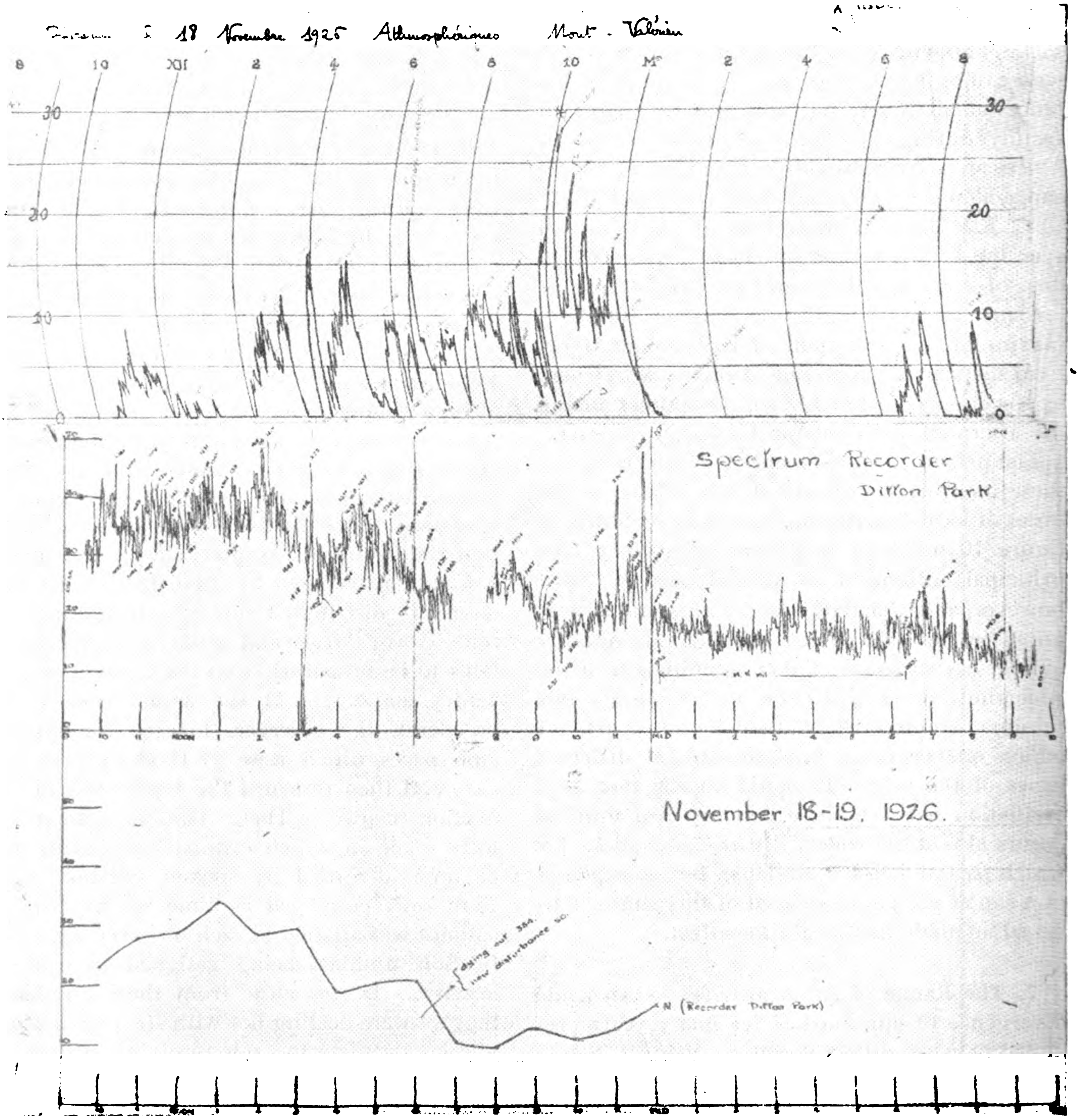

FIG. 8.

ded from the source located by the recorders. Atmospherics originating near the Azores were heard in Spain, France, England, Ireland and Scotland, atmospherics from the Atlantic doldrums were heard in Morocco, Spain, England, Ireland, Scotland and Norway, i.e. up to distances exceeding 7000 km. from the source.

One of the principal foundations of Captain Bureau's conclusion as to the short effective range of atmospherics is a correlation which he has traced by curve matching between peaks in the curve of atmospheric disturbance at a French station, and special features of the anemogram at the same station. Since wind structure is known to be very definitely a local phenomenon, the inference from this correlation would certainly be that the atmospherics recorded are also local. A comparison has been made, for a day on which the atmospheric record and the anemogram for a French station have been published by Bureau, between the French atmospheric record and a record of integrated disturbance on a narrow long-wave band at Radio Research Station. Figure 8 shows the curves together, while Table V shows the time of incidence of the principal features of the atmospheric curves to agree very much more closely than do the features of the atmospheric record with those of the wind record.

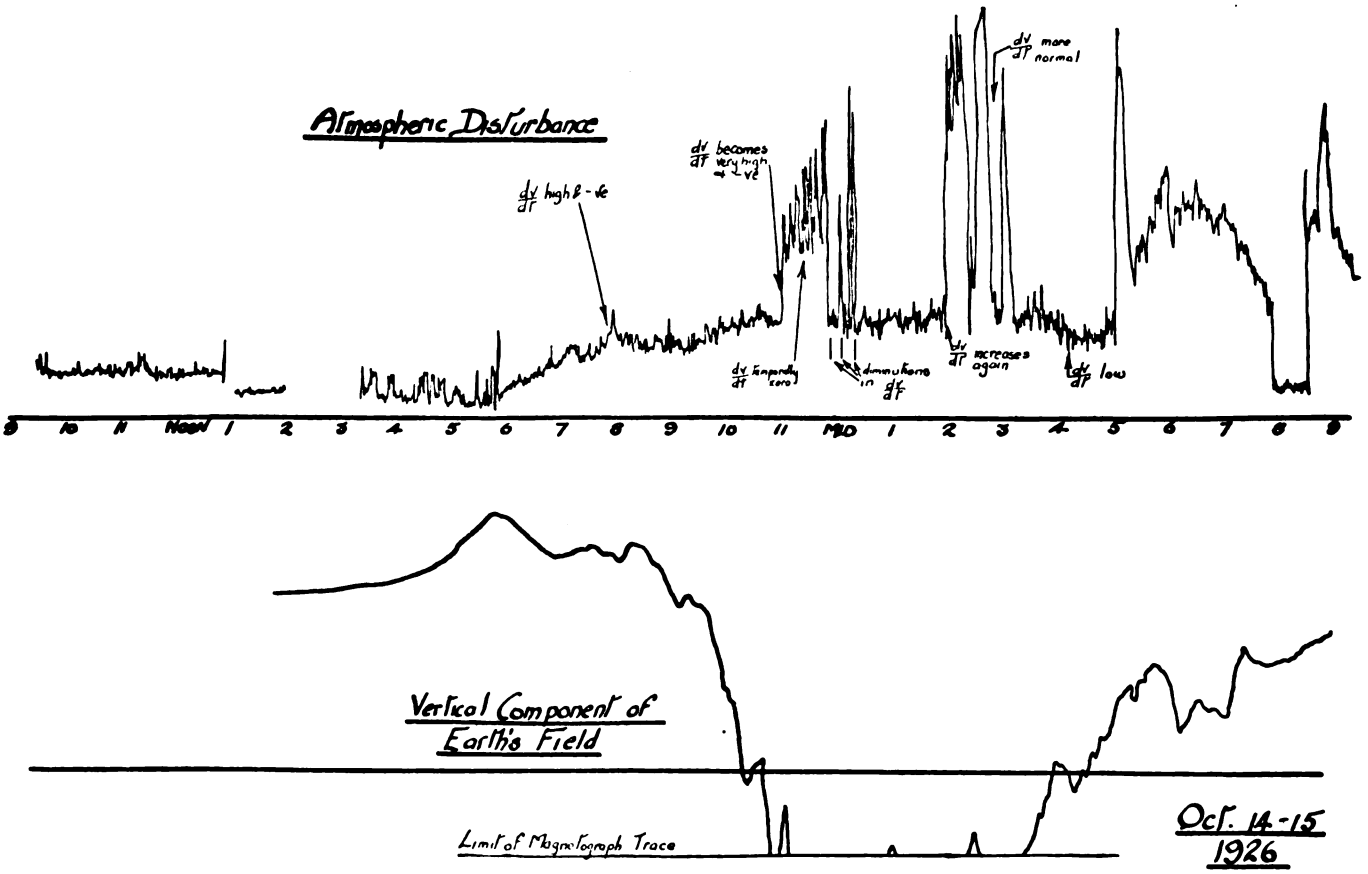

FIG. 9.

8. Terrestrial Magnetic Influences. — Figure 9 shows the curve of atmospheric disturbance on a long-wave band on the occasion of the most severe magnetic storm of 1926. It will be seen that at the times when the rate of change of the vertical component of the earth's magnetic field assumed high values, the atmospheric disturbance rose to some four times normal. This type of effect must be investigated more fully as the quantitative recording of atmospherics proceeds.

9. Conclusion. — It has not yet been possible to refer to the work now in progress in collaboration with Prof. E. V. Appleton on the distribution of the energy of atmospherics throughout the radio frequency spectrum. This work is essentially slow and must be continued for a considerable period before definite conclusions can be drawn.

Thanks are due to the Radio Research Board established under the Department of Scientific and Industrial Research for granting facilities for the work and for permission to make this communication. Thanks are also due to the staf of the Radio Research Station for their enthusiasm and untiring collaboration, to the Post Office for their collaboration in the individual direction finding work, and to the Admiralty for permission to refer to the results obtained in the cruise of H. M. S. « Yarmouth ».

TABLE I.

		R—	R+	P—	P+	
A	E	56	51	123	104	mv/m
	D	2680	2160	2580	1865	μs
Q	E	86	74	140	128	mv/m
	D	2590	2125	1325	1505	μs

TABLE II.

km. r.	v/m.		e. s. u. Moments calculated from	
	$E_{RAD.}$	$E_{ES.}$	$E_{RAD.}$	$E_{ES.}$
100	> 0.3	> 0.6	$> 1.1 \times 10^{17}$	$> 2.0 \times 10^{16}$
300	0.2	0.3	1.9×10^{17}	2.7×10^{17}
600	0.16	0.03	$2\ 3 \times 10^{17}$	2.2×10^{17}

TABLE III.

	LATITUDE	LONGITUDE	N° OF FORMS DRAWN
ENGLAND	51 1/4° N	3/4° W	8 000
AUSTRALIA	31 1/2° S	116 1/2° E	1.000
EGYPT	30° N	31 1/4° E	10.000
SUDAN	15 1/2° N	32 1/2° E	2 000

TABLE III (*continued*)

		A+	A—	Q+	Q—	Q±
N %	ENGLAND	50	30	8	5	5
	AUSTRALIA	20	31	15	32	3
	EGYPT	55	29	11	3	3
	SUDAN	50	30	15	3	3
E mv/m	ENGLAND	50	70	100	100	180
	AUSTRALIA	95	74	118	116	60
	EGYPT	82	87	133	93	82
	SUDAN	105	82	265	116	65
D μs	ENGLAND	2200	2600	3900	4000	2200
	AUSTRALIA	2170	1680	2880	2960	3130
	EGYPT	1630	2370	3090	3330	3310
	SUDAN	1260	1760	2410	3010	3280

TABLE IV.

Diurnal Variation of Field.

Local time at mid path.	1	2	3	4	5	6	7	8	9	10	11	12	13
$c_1 E k$	118			110	87½	81	78	32			36		23½
$c_2 E \sqrt{k}$	1700			1650	1500	1235	1250	550			580		360

TABLE V

November 18-19, 1926

MONT VALERIEN			DITTON PARK		
Feature.	**Ampl.**	**Time.**	**A.**	**T.**	**δT.**
—	-	—	—	—	—
X	6	1038	37	1052	14
sudden rise	0-20	45	30-39	1100	15
X	24	56	43	06	10
X	30	1105	38	15	10
X	42	06	43	16	10
X	20	13	42	23	10
X	18	20	41	31	11
N	8	24	33	35	11
X	24	25	42	37	12
X	26	29	41	40	11
X	22	38	37	49	11
X	22	45	38	57	12
X	12	52	35	1202	10
N	0	1201	31	12	11
X	12	08	41	18	10
X	12	11	42	21	10

X = Peak. N = Trough.

MONT VALERIEN			DITTON PARK		
Feature	Ampl.	Time.	A.	T.	δT.
X	8	19	42	31	12
X	6	32	44	44	12
X	8	37	45	47	10
X	8	1304	—	?	—
X	18	1047	49	1417	10
X	22	14	42	22	8
X	32	21	41	30	9
X	42	27	40	36	9
X	48	34	38	43	9
N	20	36	29	47	11
X	50	39	—	—	—
X	42	46	36	57	11
N	20	1500	0	1507—11	—
X	48	07	37	16	9
X	58	11	46	22	11
X	44	15	—	—	—
X	76	1555	30	1606	11
X	78	59	38	10	11
N	5	1604	27	15	11
X	24	07	36	17	10
X	58	14	37	23	9
X	54	19	39	28	9
X	46	25	41	37	12
X	49	31	40	40	9
N	28	35	25	43	8
X	71	45	33	54	8

MONT VALERIEN			DITTON PARK		
Feature.	Ampl.	Time.	A.	T.	δT.
sudden fall	74-34	54	35-23	1703	9
X	41	1702	—	—	—
X	11	12	36	20	8
X	6	18	36	26	8
X	10	25	33	36	11
N	31	40	22	52	12
sudden rise to					
X	46	45	32	58	13
sustained to	41	1800	31	1806	6
N	6	04	19	11	7
X	—	—	29	14	—
X	27	14	25	20	6
N			17	28	
N			17	38	
X	Marked « brouillage industriel »	28	27	39	11
N			19	46	
X		52	No record at Ditton Park.		
N		1900			
X		04			
X		11			
X		15			
X		22			
X		28			
N		37			

UTILISATION DE L'ENREGISTREMENT DES ATMOSPHERIQUES DANS L'ANALYSE METEOROLOGIQUE

par Robert BUREAU.
Office National Météorologique, Paris.

Les atmosphériques sont presqu'uniquement une manifestation électrique de l'atmosphère inférieure (troposphère). Ils sont d'autant plus nombreux et violents que les mouvements verticaux qui brassent cette atmosphère sont plus intenses. Inversement, toute cause qui s'oppose à l'existence de ces mouvements verticaux provoque également la disparition des atmosphériques, ou tout au moins les atténue dans une très large mesure.

On peut donc considérer que les atmosphériques sont l'expression électrique de l'agitation verticale de l'atmosphère dans un certain rayon autour de chaque appareil récepteur. Ils sont en quelque sorte « l'intégrale » de cette agitation verticale dans un volume (*) qui est fonction de la portée pratique des atmosphériques, ce volume étant probablement variable avec la fréquence sur laquelle est réglé l'appareil récepteur.

Suivre l'évolution des atmosphériques dans une station isolée à l'aide d'un enregistrement du phénomène nous aidera donc à suivre l'évolution des masses d'air avoisinantes vers une plus grande instabilité ou vers une plus grande stabilité verticales. Or le degré de stabilité ver-

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(*) De même que la pression barométrique est l'intégrale du poids des différentes masses d'air qui s'étagent au-dessus du baromètre.

ticale d'une masse d'air est, parmi toutes ses propriétés, l'une des plus précieuses à connaître en météorologie dynamique et dans la prévision du temps.

Une nouvelle étape sera franchie dans l'application des atmosphériques à la météorologie quand, au lieu d'utiliser la courbe représentative de l'évolution du phénomène en une station isolée, on pourra utiliser les mêmes courbes relatives à plusieurs stations réparties sur une suffisante étendue de territoire (étude en réseau). Cette étude en réseau donne déjà des résultats dignes d'intérêt quand on utilise non pas les enregistrements d'appareils, mais simplement les observations à l'oreille faites avec méthode dans un *réseau* de postes récepteurs.

§ 1. — Utilisation des enregistrements d'une seule station.

Les exemples qui suivent sont relatifs aux atmosphériques enregistrés près de Paris, soit à Saint-Cyr, soit au Mont Valérien, par les soins de l'Office National Météorologique. A Saint-Cyr on enregistre le nombre d'atmosphériques par unité de temps et au Mont Valérien, « l'activité » des atmosphériques.

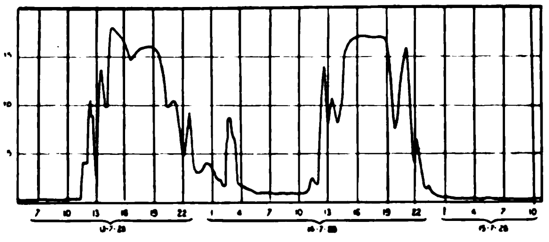

FIG. 1.
Atmosphériques-Mont-Valérien.
Courbe résumée, 13 au 15 juillet 1928,
f = 136 Kc/s (2,200 m.).

a) Les 13 et 14 juillet 1928, les cartes isobariques semblent n'indiquer rien d'autre que la prolongation de la situation anticyclonique préexistante. Par contre, l'enregistrement des atmosphériques (fig. 1) révèle l'apparition d'un régime d'atmosphériques stagnants (*) (croissance brutale vers 11 h. 30, maximum vers 15 h., chute progressive jusqu'à 22 h. environ) et annonce ainsi la présence probable d'un courant de perturbations météorologiques au sud de l'anticyclone. Une analyse météorologique plus détaillée que le simple examen isobarique confirme l'existence de ce courant de perturbations (la figure 2 montre la trace de ce courant au sol sur le sud de la France le 13 juillet à 18 heures) dirigé dans l'ensemble du sud-ouest au nord-est.

b) Du 18 au 23 juillet 1928, la France est encore sous l'action de l'anticyclone. Cependant, cette fois encore, la courbe des atmosphériques ne correspond pas à une situation anticyclonique et ne présente pas la régularité (montée au coucher du soleil, haute valeur la nuit, chute brusque au lever du soleil) des atmosphériques d'anticyclone. La figure 3 reproduit la courbe de fréquence des atmosphériques du 18 au 23 juillet. Cette courbe est assez irrégulière

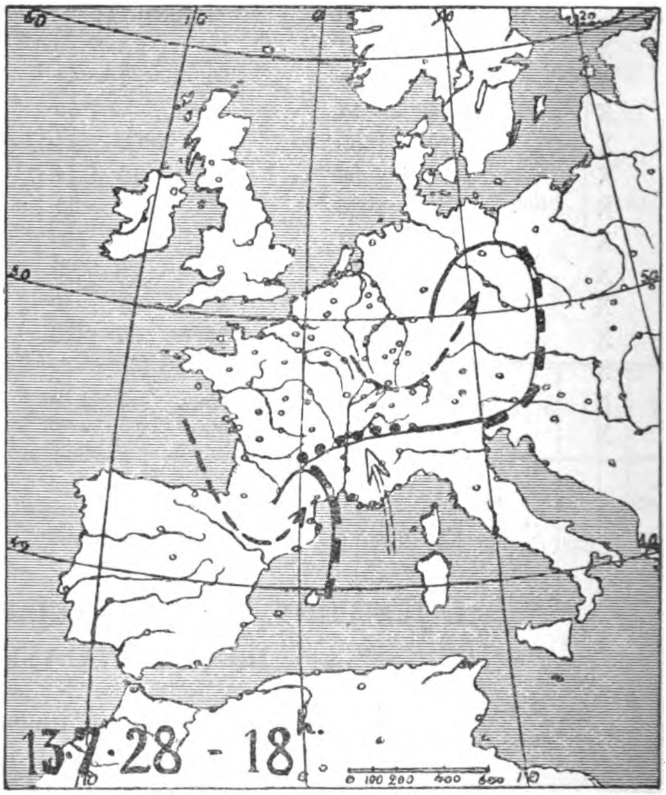

FIG. 2.
Situation météorologique en France, le 13 juillet 1928, à 18 heures.

Légende :
——— discontinuité.
▬ ▬ ▬ ▬ front froid.
● ● ● ● front chaud.
- - - - - -> air froid.
= = = => air chaud.

(*) Atmosphériques stagnants : voir R. BUREAU, *Comptes-rendus Académie des Sciences*, t. CLXXX, 1925, p. 529.

et présente de très grandes différences d'un jour à l'autre. Les deux variations diurnes régulières (maximum de nuit des atmosphériques d'anticyclones, maximum d'après-midi des atmosphériques stagnants) laissent apparaître plus ou moins leur action dans l'ensemble. Dans le détail, la courbe reflète fidèlement les événements principaux de l'évolution météorologique au cours de ces six journées. Il serait trop long, et surtout cela nécessiterait trop de figures, de le montrer ici en détail, signalons seulement à titre d'exemple ce qui suit :

Les atmosphériques nombreux du 18 juillet (variation diurne du type « atmosphériques stagnants ») correspondent à la dernière journée de la situation orageuse dont le début fut annoncé par les atmosphériques stagnants du 13. Le courant des perturbations météorologiques longeant le sud de l'anticyclone et qui provoquait cette situation et ces atmosphériques cesse ensuite et avec lui cessent les atmosphériques stagnants.

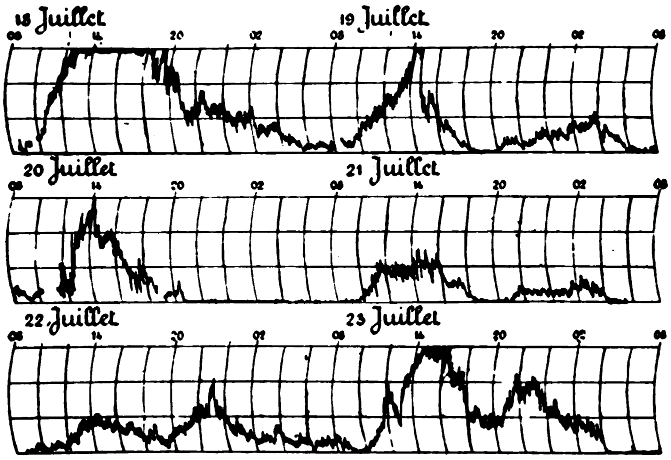

FIG. 3.

Atmosphériques à Saint-Cyr (fréquence).
Courbes détaillées, 18 au 23 juillet 1928,
f = 50 Kc/s (6,000 m.).

Cette disparition du courant méridionnal ne provoque cependant pas la réapparition des atmosphériques nocturnes réguliers. Ceux-ci disparaissent même presque totalement dans la nuit du 21 au 22 et la chute matinale est presque entièrement masquée le 23 juillet. Tout ceci est la conséquence du passage en altitude des prolongements vers le sud, sous forme d'occlusions, des perturbations du front polaire dont le courant de perturbations longe au nord l'anticyclone (coïncidence des maxima de la courbe d'atmosphériques avec le passage des occlusions à Paris, occlusions à caractère de front froid, disparition des atmosphériques due à un affaissement accentué des masses d'air). L'influence du courant de perturbations septentrional a donc remplacé celle du courant méridional pour commander, malgré l'aspect anticyclonique de la situation, l'évolution des atmosphériques.

c) Il n'en faudrait pas conclure que, pour une raison ou pour une autre, les atmosphériques d'anticyclone sont toujours absents des anticyclones. On trouve un bel exemple de variation diurne anticyclonique pendant les premiers jours de septembre 1928 (fig. 4). Ces beaux exemples se rencontrent souvent en France lorsqu'on se trouve au sud-est de l'anticyclone, dans des vents d'est

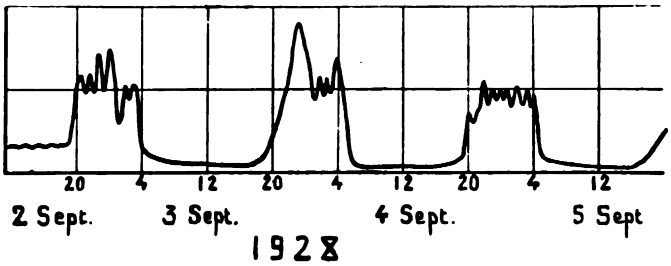

FIG. 4.

Atmosphériques-Mont-Valérien.
Courbe résumée, 2 au 5 septembre 1928,
f = 555 Kc/s (540 m.).

D'autres exemples de maxima nocturnes réguliers, surtout par la fixité des heures de croissance le soir et de décroissance le matin, se rencontrent en hiver même en dehors des anticyclones lorsqu'on se trouve loin du trajet des discontinuités météorologiques.

Les trois exemples d'été que nous venons de donner montrent comment l'évolution des atmosphériques en une station permet, en période anticyclonique, d'acquérir une indication qualitative sur l'extension de l'anticyclone en altitude et sur l'origine des masses d'air qui circulent par-dessus les couches basses de cet anticyclone. Nous avons vu que ces masses d'air peuvent être amenées soit par un courant de perturbations méridional (pseudo front polaire), soit par un courant de perturbations septentrional (front polaire). Sur le mécanisme différent de leur action, nous n'avons pas à nous étendre ici, il fera l'objet d'autres publications. Qu'il nous suffise d'avoir indiqué de quelle manière l'étude d'une courbe d'atmosphériques peut devenir une « aérologie indirecte » (*).

L'étude comparée des courbes obtenues simultanément dans un réseau de stations peut nous apprendre plus encore sur la structure de l'atmosphère en altitude.

§ II. — Utilisation des relevés d'un réseau de stations.

Les deux exemples que nous allons signaler sont relatifs non pas à des enregistrements, mais à de simples relevés d'observations effectuées au moins d'heure en heure, aussi longtemps que possible chaque jour, et quand on le peut au cours des vingt-quatre heures, par un réseau de postes récepteurs de T.S.F.

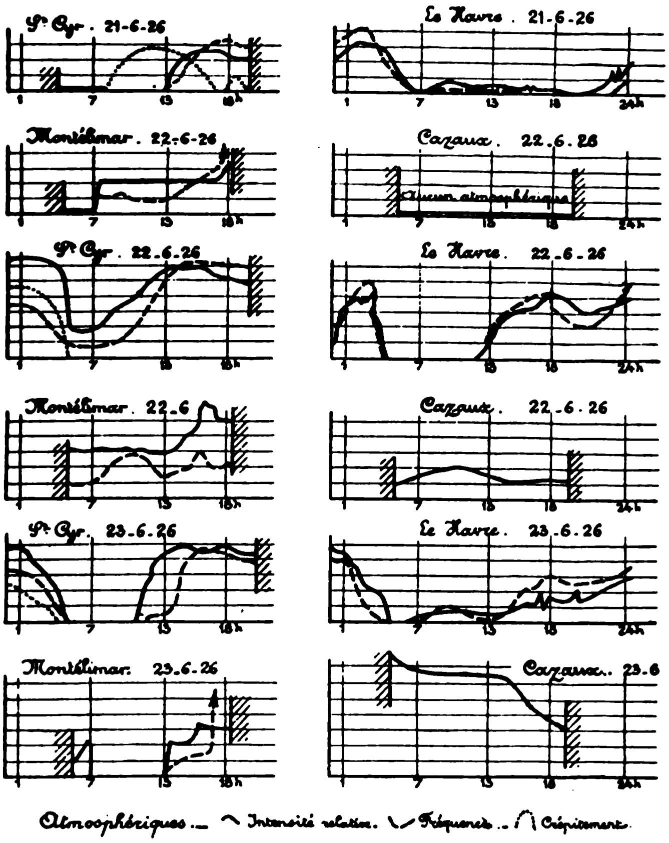

FIG. 5.

Évolution des atmosphériques en France, les 21, 22 et 23 juin 1926.

A) Cas des 21, 22 et 23 juin 1926. — La figure 5 donne l'évolution, au cours de ces trois journées, des parasites atmosphériques à Saint-Cyr (20 kilomètres ouest de Paris), Le Havre, Montélimar, Cazaux (au sud-ouest de Bordeaux). On voit tout d'abord à quel point les courbes diffèrent le même jour d'une station à l'autre et dans une même station d'un jour à l'autre.

D'autres renseignements nous sont fournis sur ces trois journées par les cahiers de réception radiotélégraphique des postes météorologiques français. D'après cette documentation — relativement très homogène, mais incomplète, car la plupart des postes sont fermés la nuit — la journée du 22 juin est la plus troublée de la deuxième quinzaine du mois. D'autre part presque tous les brouillages provoqués par les at-

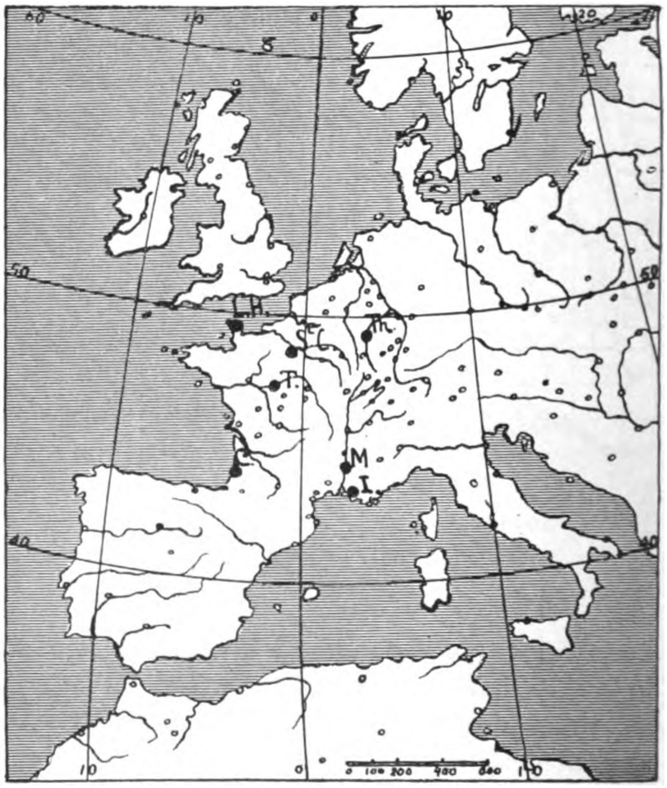

FIG. 5a.

Emplacement des principales stations d'observation des atmosphériques :

L. H. : le Havre.
St-C. : Saint-Cyr.
Th. : Thionville.
T. : Tours.
C. : Cazaux
M. : Montélimar.
I. : Istres.

(*) Nous n'avions pas employé ce mot dans la communication orale faite à Bruxelles. Nous l'empruntons à l'ouvrage de Tor Bergeron, paru depuis (« Uber die dreidimensional verknüpfende Wetteranalyse-Geofysiske publikasjoner, vol. V, nº 6 ; Oslo, 1928) dans lequel l'auteur exposé les méthodes *météorologiques* d'analyse constituant une aérologie indirecte étonnamment précise. Le présent travail n'est qu'une très modeste contribution électrique dans le même sens.

mosphériques sont localisés dans l'est de la France (Lyon, Mulhouse, Nancy, Strasbourg, Thionville) et en Rhénanie (Mayence) et sont signalés à partir de 10 heures du matin.

L'influence de cette zone d'atmosphériques forts se fait sentir au-delà de la zone affectée par les brouillages. Voici quelques renseignements à ce sujet.

Thionville. Augmentation brusque des atmosphériques vers 10 h., diminution provisoire à 14 h. 30 et très forte augmentation vers 15 h. 30.

Saint-Cyr. Augmentation vers 9 ou 10 h. (l'intensité augmente d'abord vers 8 h. 30 puis la fréquence vers 10 h.) puis atmosphériques forts à partir de 12 h.

Tours. Brusque augmentation de l'intensité à 13 h., de la fréquence à 14 h. Affaiblissement à 17 h. 30.

L'influence de la zone de brouillage de l'Est se fait donc sentir à Saint-Cyr et à Tours. Mais à Tours, elle est beaucoup plus affaiblie qu'à Paris. Elle s'y manifeste plus tard et y disparaît plus tôt.

Le Havre. La même influence se manifeste encore, mais à un degré moindre. En particulier les atmosphériques assez forts n'apparaissent que vers 12 h.

En d'autres régions de la France, l'action de la zone de brouillage de l'Est de la France ne se retrouve plus, ou tout au moins, se trouve noyée dans d'autres phénomènes

A *Montélimar,* on n'observe pas de disparition d'atmosphériques au cours de la matinée. Ce fait est exceptionnel.

A *Istres,* l'intensité des atmosphériques est plus grande le 22 que les 21 et 23. Les atmosphériques y sont en croissance continue à partir de 12 h.

Mais à *Cazaux,* l'évolution des atmosphériques au cours de ces trois journées est totalement différente. Aucun le 21 (calme plus affirmé que les jours normaux). Le 22, atmosphériques de force et fréquence moyennes avec maximum vers 10 h. et diminution l'après-midi. Le 23 par contre, atmosphériques violents et très nombreux dès la première observation (5 h.). Diminution rapide dès 15 heures.

Au *Maroc* (Rabat), les courbes atmosphériques n'ont aucun rapport avec celles de France. Le 22 en particulier, deux périodes d'atmosphériques violents (9 h. à 11 h. et à partir de 14 h.)) sont séparées par une accalmie.

En résumé, même avant d'examiner la situation météorologique, et par le simple examen synoptique de l'ensemble des observations d'atmosphériques dans un réseau de postes, on peut déjà constater :

a) Que des atmosphériques particulièrement violents sévissent dans l'Est de la France et y sont généralisés dès 10 h. du matin.

b) Que, si l'on retrouve dans le Nord et le Centre de la France une répercussion probable des atmosphériques de l'Est, il n'en est plus de même dans le Sud, le Sud-Ouest et au Maroc où l'évolution des atmosphériques n'a plus guère de rapport avec ce qui se passe dans l'Est du pays.

Voici maintenant un résumé très succinct de la situation météorologique :

1° Tandis que l'anticyclone des Açores s'étend sur le Sud-Ouest de la France depuis le 19 juin, une invasion polaire venant du Nord-Ouest, vient brutalement chasser une masse d'air continental très chaud (vent du Sud) qui couvrait auparavant l'Allemagne du Nord, provoquant de nombreux orages sur l'Allemagne centrale et un temps de traine (nuages bourgeonnants, éclaircies, etc... au total indices d'une atmosphère à gradient thermique vertical accentué et donc très instable) sur l'Est de la France. L'ensemble de ces phénomènes est sans aucun doute la source des atmosphériques violents de l'Est de la France.

2° Le Sud-Est de la France est sous l'action d'une dépression qui s'étend sur l'Italie et qui renforce l'appel d'air polaire dans la région du Rhône. D'où probablement, sous l'action prédominante de cet air polaire instable la destruction des caractères normaux de la variation diurne à Montélimar (croissance les matins des 21 et 22).

3° Le Sud-Ouest de la France est sous l'action d'un courant de perturbations qui, en apparence tout au moins, longe en sens inverse des vents au sol l'anticyclone par le Sud. Est-ce là l'un de ces courants de perturbations indépendants du front polaire et dont l'intervention en France y déclenche en été le vacarme post méridien des atmosphériques stagnants? (Voir plus haut paragraphe I.) L'observation des courbes d'atmosphériques nous amène à rejeter cette hypothèse: le courant de perturbations du Sud de l'anticyclone a sur l'évolution des atmosphériques les effets classiques d'un courant de perturbations du front polaire principal: ses noyaux de baisse barométrique y provoquent la diminution anormale des atmosphériques (voir Cazaux le 21). Et ses noyaux de hausse y provoquent des atmosphériques violents aux heures les plus quelconques, et même aux heures de calme normal (à 10 heures Cazaux le 23).

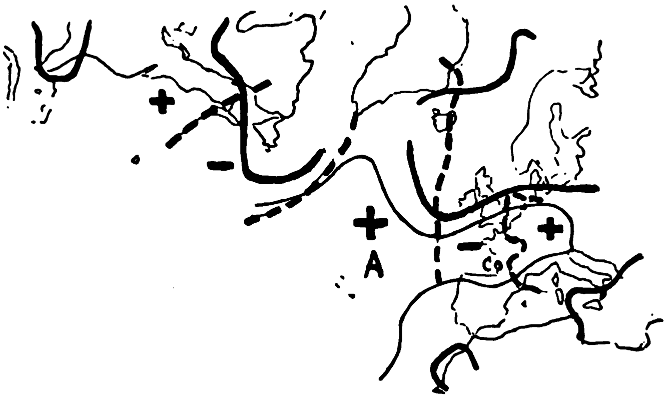

FIG. 6.

Situation météorologique sur l'Atlantique et sur l'Ouest de l'Europe, le 21 juin 1926, à 1 heure du matin.
Courbe en traits pleins : isobares 760 mm.
Courbe en traits interrompus : courbes de variation barométrique nulle.
+ : régions de variations barométriques en 24 heures positives.
— : régions de variations barométriques en 24 heures négatives.
A : Anticyclone atlantique.

L'observation des atmosphériques nous amène donc aux conclusions suivantes :

a) Le courant de perturbations méridionales n'est qu'une branche dérivée du front polaire, et non un pseudo front indépendant de celui-ci.

b) Le Nord et le Centre de la France se trouvent dans la masse d'air polaire dont la partie principale a envahi l'Allemagne.

c) Une partie de cette masse d'air est descendue vers le Sud-Est de la France, attirée par la dépression méditerranéenne.

d) Le temps sur le Sud-Ouest de la France est commandé par les masses d'air qui circulent en altitude au Sud de l'anticyclone atlantique.

Une analyse météorologique détaillée confirme ces conclusions En particulier l'examen des cartes météorologiques de l'Atlantique Nord au cours des journées étudiées et des journées précédentes montre bien que les perturbations qui touchent le Sud-Ouest de la France ne sont que la partie méridionale de perturbations du front polaire qui ont été scindées en apparence par l'anticyclone atlantique (fig. 6).

Jointe aux autres moyens d'analyse météorologique, l'étude synoptique de l'évolution des atmosphériques facilite dans une très large mesure l'analyse des masses d'air et des surfaces de discontinuité.

B) CAS DU 27 AOUT 1928. — Les observations d'atmosphériques assurées en France au cours de cette journée montrent que ceux-ci ont évolué de manière différente en quatre régions (fig. 7).

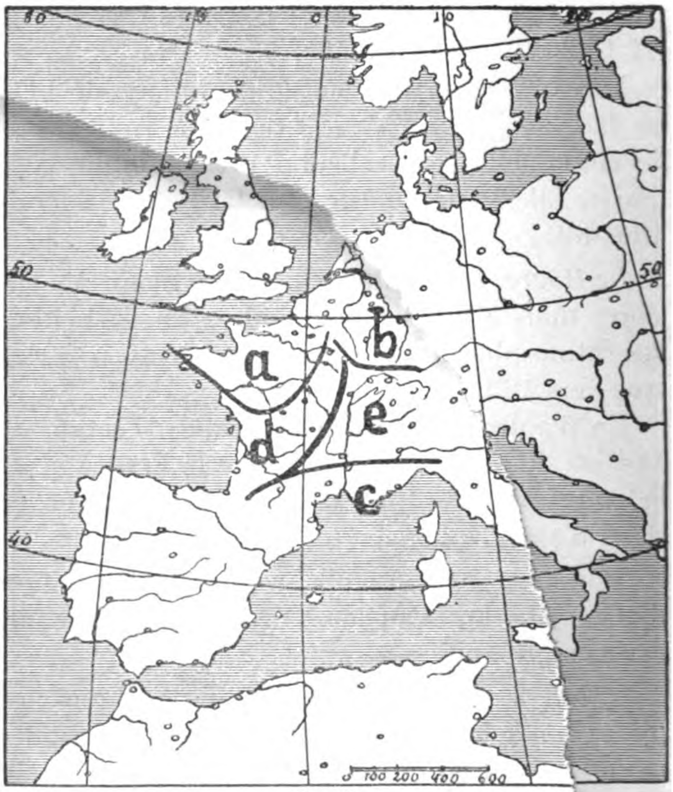

FIG. 7.

27 août 1928: *a*, *b*, *c*, régions dans lesquelles les atmosphériques évoluent de la même manière (voir le texte). — Dans la région *e*, aucune observation.

a) Dans la région parisienne et dans la Touraine, assez grande activité des atmosphériques même aux heures habituelles du minimum diurne. Ceci correspond au caractère classique de la masse d'air polaire qui recouvre ces régions.

b) Dans l'Est de la France et en Rhénanie, atmosphériques forts apparaissant dans la journée mais à des heures successives (Thionville vers 8 h., Mayence vers 14 h.). Ils sont liés à la formation et aux mouvements d'un front secondaire dans la masse d'air polaire.

c) Dans le Sud de la France, matinée très calme, mais atmosphériques forts apparaissant assez brutalement à 13 heures (*).

Cette évolution est due à l'action successive d'un front chaud (fig 8) puis d'un front froid apparaissant sur la gauche de la langue d'air chaud.

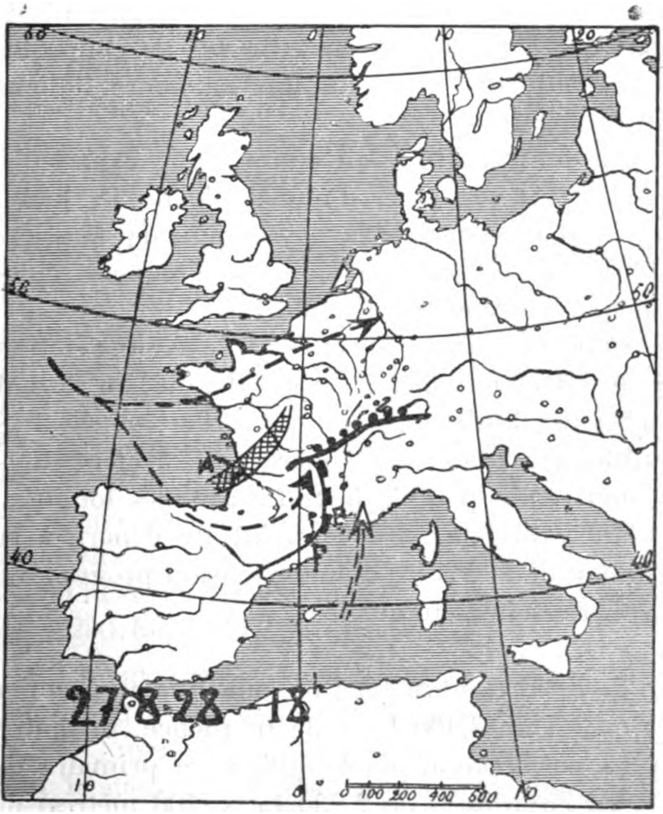

Fig. 8.
27 août 1927. Situation à 8 heures.
Zone hachurée = zone de pluie. — Pour les signes conventionnels, voir figure 2.

d) Dans le Sud-Ouest et une partie du Centre de la France, journée (les observations n'y ont été faites que de 5 à 18 h.) remarquablement calme. Au premier examen ce calme peut paraître anormal. Cependant il trouve sa contrepartie dans l'aspect des nuages observés. Dans la région considérée les nuages présentent beaucoup moins qu'ailleurs les caractères bourgeonnants révélateurs d'une grande instabilité verticale. Ces deux séries d'observations, celle des nuages et celle des atmosphériques vont nous aider à donner une interprétation des phénomènes que voici :

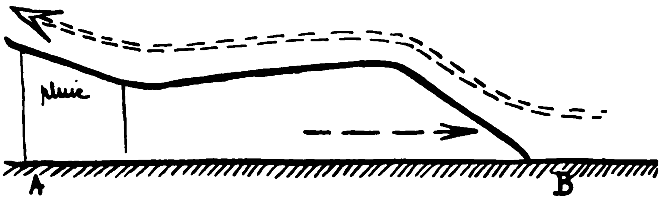

Fig. 8*a*.
Coupe verticale suivant AB de la figure 8.

L'air chaud décelable au sol sur la côte méditerranéenne continue en altitude son chemin vers l'Ouest et le Nord au-delà du front froid F (fig. 8). Il circule alors au-dessus de l'air froid non seulement sans mouvement ascendant notable, mais probablement avec une composante descendante par suite de l'affaissement de l'air polaire sous-jacent (*). Puis il rencontre sur la côte atlantique un renforcement de la masse d'air polaire dont l'épaisseur augmente. L'air chaud est de nouveau soulevé (front chaud en altitude) et provoque des pluies continues dans le Sud-Ouest de la France. Or l'affaissement des masses d'air est l'une des principales causes de la disparition des atmosphériques (**). D'où l'absence d'atmosphériques notables dans la région *d*.

C'est ainsi que des observations qualitatives très simples sur l'évolution des atmosphériques, assurées dans un réseau de postes, peut aider à préciser la structure de l'atmosphère en altitude.

(*) Cette évolution est relativement locale puisqu'on ne la retrouve ni dans le Nord, ni au Sud : en Tunisie (Bizerte), calme presque complet de 4 heures à 18 heures au Maroc (Rabat), calme de 9 heures à 11 heures ; dès 11 heures, accroissement continu des atmosphériques.

(*) Cet affaissement est, incomplètement réalisé, le même phénomène que celui signalé par M. Petitjean en Algérie où il est assez fréquent. M. Petitjean a montré que dans ce pays, l'air chaud peut en s'abaissant entre deux masses d'air froid qui s'écartent, descendre jusqu'au sol (phénomène inverse de l'occlusion).

(**) R. Bureau, *La Météorologie*, T. III, Nouvelle série, 1927, p. 287.

EXPERIENCES DE COMMUNICATIONS PAR ONDES COURTES

par G. PESSION et G. MONTEFINALE.

1. *Premières expériences.* — Dès 1911, année où fut inaugurée la première liaison radiotélégraphique entre la station à grande puissance de Coltano et la station analogue de Massaua, la Marine royale italienne fut chargée de l'exploitation des services radiotélégraphiques d'État et commerciaux avec les deux colonies italiennes de l'Afrique Orientale et, ultérieurement, avec d'autres localités étrangères et coloniales, de même qu'avec les navires de guerre ou de commerce, dispersés dans des mers lointaines.

L'exploitation de ces services permit aux techniciens de la Marine royale d'étudier et d'appliquer de nouvelles améliorations.

Pour ce qui concerne les ondes courtes, dès 1923, grâce aux expériences du sénateur Marconi, on comprit et on apprécia les remarquables avantages techniques et économiques que l'on pouvait obtenir par l'emploi dans les radiocommunications transocéaniques et transcontinentales, des très hautes fréquences.

Pour les premières expériences on employa des fréquences d'environ 2,400 Kc/s (ondes de 125 mètres) avec des émetteurs d'environ 2 Kw à l'alimentation des triodes. Ces appareils furent construits et montés dans la station radiotélégraphique transcontinentale de Rome S. Paolo (I. D. O.).

Pendant le jour, les appareils atteignirent normalement une portée approximative de 600 kilomètres, tandis que pendant la nuit les signaux émis sur 125 mètres étaient perçus même de Massaua (3,900 kilomètres).

La puissance de ces appareils, alimentés uniquement avec du courant triphasé industriel, fut portée ensuite à 3 Kw, en expérimentant des schémas, des antennes et des contrepoids de différents types.

Lors du voyage en l'Amérique du Sud du R. N. *San Marco*, commandé par le Prof^r Alberto Alessio, capitaine de vaisseau, l'Arsenal Royal de la Spezia installa sur ce navire, avec la coopération d'un jeune amateur, M. Ducati, le premier poste mobile à ondes courtes. On put effectuer des expériences très intéressantes entre le vaisseau et la station de S. Paolo; ces expériences confirmèrent pleinement les résultats obtenus antérieurement par le sénateur Marconi, résultats qui avaient déjà été entrevus au cours des essais effectués par plusieurs amateurs italiens et étrangers.

En janvier 1924, au cours d'une expérience de service pratique, d'une durée de 18 jours, on put transmettre à la station de Massana 11,545 mots taxés; pour 1,599 desquels seulement répétition fut demandée.

Cette expérience fut effectuée avec une station située dans une localité tropicale, où l'on ressent très fort l'influence des perturbations électro-atmosphériques qui auparavant, avaient toujours rendu pénible le trafic à ondes longues. Cette expérience fut le point de départ, à la station de S. Paolo, d'une extension progressive des très hautes fréquences.

2. *En décembre 1924* on substitua au premier appareil de 2,400 Kc/s de fréquence, un autre plus perfectionné d'une puissance primaire de 7 Kw environ et de 2,830 Kc/s (106 mètres) de fréquence.

Les résultats ainsi obtenus furent considérables : les signaux de S. Paolo furent perçus nettement à Massaua en janvier 1925, pendant 14 heures sur 24; alors que, avec l'émetteur Poulsen de 250 Kw et de 27 Kc/s (presque 11,000 mètres), on n'avait pu communiquer utilement que pendant 6 heures environ par jour.

Au cours d'une autre expérience d'une durée de 20 jours (janvier et février 1925), on put transmettre à Massaua 19,687 mots taxés, pour 60 desquels seulement on demanda répétition.

Ce pourcentage n'avait jamais été atteint avec un émetteur à ondes longues de 215 Kw. Il est à remarquer que dans la nuit du 6 au 7 février (époque des grands orages dans les vallées éthiopiennes), la station de Massaua signala des décharges orageuses.

Ces résultats contrastaient beaucoup avec les difficultés qui caractérisèrent de 1910 à 1926, les communications à ondes longues entre l'Érythrée et l'Italie, non seulement lors de l'emploi des vieux appareils de grande puissance à étincelle, mais aussi après la mise en exploitation de la transmission à arc Poulsen Rome-Massaua.

Vers la fin de 1925 le trafic total de S. Paolo pour la fréquence de 2,800 Kc/s s'élevait mensuellement à 42,000 mots.

Il faut remarquer que le même émetteur de 2,800 Kc/s était utilisé pour des liaisons unilatérales avec des navires de guerre stationnant dans l'Extrême-Orient et pour des expériences avec des navires de l'Océan Atlantique. En novembre 1925, la station de S. Paolo put se maintenir en communication ininterrompue avec le transatlantique *Duilio* en route pour New-York, il transmit pendant la traversée, 4,500 mots, qui furent reçus avec une régularité parfaite jusqu'à l'entrée dans le port américain. En même temps, la station de S. Paolo établissait avec un navire de guerre stationnant à Colombo, une communication bilatérale d'abord à la fréquence de 3,300 Kc/s (environ 90 mètres), et ensuite à celle de 4,290 Kc/s (70 mètres environ).

Ce même navire, pendant son séjour à Colombo, et pendant une croisière sur la côte du Somali, maintint un contact nocturne régulier avec la station de S. Paolo, en transmettant près de 40,000 mots, et en utilisant une puissance primaire de 300 watts.

Toujours, en utilisant l'appareil de 2,800 Kc/s, la station de S. Paolo avait transmis de novembre 1924 à février 1926, environ 630,000 mots taxés, à des stations fixes et mobiles situées à grande distance, et fonctionnant normalement entre 20 et 2 heures T. M. G.

3. *Augmentation de la fréquence d'émission.* — Dans le but d'éliminer quelques inconvénients qui se produisaient dans les communications avec des postes d'outremer, en employant la fréquence de 2,800 Kc/s, mais surtout pour diminuer l'influence des décharges atmosphériques sur la réception rendue difficile même par les phénomènes d'atténuation (fading), on décida, au commencement de l'année 1926, de construire un appareil de puissance primaire de 6 Kw, avec une fréquence de 4,550 Kc/s (66 mètres environ) remarquablement supérieure à celle de l'appareil précédent. Par la mise en service de ce nouvel appareil on obtint immédiatement, des améliorations remarquables dans les services à grande distance.

Cela amena la suppression de la fréquence de 2,800 Kc/s, et l'adoption définitive dans les différents services de celle de 4,550 Kc/s. Les répétitions de mots dans le service normal furent toujours de moins de 2 % des mots taxés.

Dès lors, on entrevit que même ayant obtenu, par l'adoption d'une fréquence plus haute, une immunité plus sensible des perturbations électro-atmosphériques, on n'aurait pu réaliser l'avantage que l'on se proposait d'obtenir d'une période plus prolongée de transmission dans le jour solaire, parce que le fonctionnement, de jour et de nuit, des ondes de 106 et de 66 mètres n'était pas suffisamment différent.

On décida alors la construction d'un appareil de la même puissance, mais avec une fréquence d'émission bien plus élevée, on s'arrêta sur celle de 8,000 Kc/s ($37^{m}5$ environ) (*).

En utilisant l'appareil émetteur à onde de $37^{m}5$, on eut l'avantage de pouvoir commencer le service avec l'Afrique Orientale avec deux heures d'avance sur l'heure où l'on commençait habituellement sur l'onde de 66 mètres et de le prolonger de deux autres heures au matin (**).

(*) On peut trouver les détails de construction des différents appareils émetteurs et récepteurs à onde courte construits et montés dans la station de S. Paolo, de même que les résultats obtenus dans le service pratique, dans les publications ci-après de l'Institut Electrotechnique et Radiotélégraphique de la Marine Royale :

Brochure n° 32 : G. PESSION et A. PIZZUTI : Contributo sperimentale alla radiotelegrafia con onde corte (1925) ;

Brochure n° 36 : G. PESSION et G. MONTEFINALE : Esperienze di radiotelegrafia commerciale ad onde corte (1926) ;

Brochure n° 40 : G. PESSION et G. MONTEFINALE : Il centro radiotelegrafico di Roma (S. Paolo, 1927).

(**) La démonstration de ces résultats résulte des graphiques contenus dans la publication n° 36 (voir note précédente).

4. *Étendue du réseau.* — Les résultats intéressants indiqués ci-dessus amenèrent à reproduire et à étendre l'usage des appareils à très haute fréquence; des exemplaires de ces appareils furent envoyés à des stations fixes lointaines dont l'exploitation était confiée à la Marine royale, et qui jusqu'alors exécutaient un service unilatéral avec la station de S. Paolo, recevant à onde courte et émettant avec des appareils Poulsen à onde longue.

La première installation transcontinentale de la sorte fut faite au Somali, pour lequel la communication avec la métropole avait été assurée pendant près de quinze années par l'intermédiaire de la station de Massaua par transmission à ondes longues, mais avec de fréquentes interruptions dues aux conditions atmosphériques, qui parfois se prolongèrent pendant deux ou trois jours consécutifs.

L'installation radiotélégraphique de 6 Kw de la station de Afgoi permit, dès la première mise en service en 1926, la correspondance directe entre le Somali Italien et l'Italie, avec un trafic journalier de cette colonie avec la métropole de plus de 2,500 mots taxés et une grande amélioration des communications d'État et des communications privées.

Ensuite, on mit en service un appareil du même type à l'Asmara, il donna des résultats identiques; on affecta plus tard d'autres appareils aux communications radiotélégraphiques d'État et commerciales exploitées par la marine entre le Dodecannèse et l'Italie, tandis qu'un appareil tout à fait identique fut installé dans une station radiotélégraphique d'Extrême-Orient, établissant ainsi des communications directes avec l'Italie, à la distance remarquable de 10,000 kilomètres.

Quelques temps plus tard, on porta l'onde normale de la station de S. Paolo à la fréquence de 9,390 Kc/s (32 mètres environ), elle semblait la mieux indiquée à certaines heures, pour les communications existantes soit avec les stations fixes d'outremer, soit avec les navires de guerre ou de commerce dans les océans.

Parmi les perfectionnements apportés en dernier lieu aux appareils émetteurs de la station de S. Paolo, on doit remarquer l'emploi de triodes à anode refroidi pour des puissances de l'ordre de 25 Kw; grâce à ces appareils et à l'emploi des ondes de fréquence de près de 8,800 Kc/s (34 mètres environ), les communications à très grande distance furent beaucoup améliorées, de sorte qu'on a pu porter le rayon d'action de cette station à 6,000 kilomètres environ en plein jour.

5. *Observations techniques.* — Le service intense et prolongé de la station de S. Paolo a permis de faire des observations qui, même n'ayant pas le résultat d'expériences systématiques à caractère scientifique, présentent toutefois quelque intérêt.

Ce qui fut très important à constater pour ces longues expériences fut la parfaite régularité du fonctionnement des ondes courtes.

Tous les jours, aux heures de service possibles, connues et déterminées, les signaux sont de force constante, uniformes et presque indépendants des perturbations atmosphériques.

Les atténuations (fading) ne déterminent pas ordinairement de dérangements remarquables dans le service au téléphone.

En général, tout le service avec les stations fixes éloignées et avec les navires à l'étranger est effectué de manière satisfaisante en employant l'appareil à onde de 32 mètres (6 Kw), tandis que celui de 25 Kw (onde de 34 mètres) est réservé pour les cas où une plus grande puissance est demandée. En hiver la station de Pékin reçoit beaucoup mieux l'onde de 66 mètres, tandis qu'en été, celle de 32 mètres, est à préférer.

Des nombreuses expériences faites, se dessine parfaitement le maintien des différentes ondes employées à la station de S. Paolo. En descendant de 106 à 32 mètres, on a expérimenté les ondes de 106, 80, 66, 50, 40, 34, et 32 mètres, on remarque aisément que les ondes plus longues présentent une différence plus sensible entre la portée diurne et la portée nocturne. Avec 106 et 80 mètres la portée diurne est très limitée, tandis que la nocturne est bien grande (presque vingt-cinq fois la diurne avec les dispositifs employés à la station de S. Paolo). L'onde de 50 mètres a une portée diurne plus remarquable.

Avec l'onde de 40 mètres on commence à noter les zones de silence pendant la nuit : la réception va diminuant alors rapidement jusqu'à une distance de 50 ou 100 kilomètres — suivant la puissance — après cette zone elle reste incertaine pour une zone plus ou moins étendue, suivant la saison et l'heure, pour reprendre ensuite et garder son intensité jusqu'à une très grande distance.

L'onde de 32 mètres a une portée diurne supérieure à toutes les précédentes, mais il se produit, la nuit surtout, des zones de silence très étendues à des distances variables (*skip distances*) dans un rayon qui, pour la puissance de 6 Kw, est de 500 à 1,500 kilomètres suivant les saisons. En employant l'onde de 32 mètres, 6 Kw par exemple, on peut bien communiquer — et en plein jour — avec les navires sur la côte de l'Afrique du Nord ou bien dans l'Égée, tandis que la nuit on communique avec difficulté et pendant certaines heures pas du tout avec Rhodes, ni souvent même avec les stations très proches de La Spezia, La Maddalena, Naples; les signaux, au contraire, arrivent très forts à Mogadiscio, à Massaua et à Pékin.

On a pu s'assurer que la zone devient de plus en plus immunisée aux décharges atmosphériques à mesure que l'onde diminue; par exemple, à la station d'Afgoi, outre l'appareil de 6 Kw, à onde de 70 mètres, on a installé un second appareil de puissance inférieure, à onde de 30 mètres : très souvent, le soir, la réception à la station correspondante de Monterotondo sur l'onde de 70 mètres est rendue impossible par les perturbations atmosphériques, tandis qu'elle est assez facile sur l'onde de 38 mètres, de sorte qu'en emploie désormais cette dernière onde pour l'échange de la correspondance.

Nos stations d'Extrême-Orient ont relaté qu'elles peuvent recevoir le jour, de manière satisfaisante et pendant plusieurs heures, les ondes de 15 mètres, ce qui a fait décider l'installation d'un nouvel appareil sur cette longueur.

Le tableau ci-dessous donne la statistique du trafic de la station de S. Paolo, depuis l'époque (1923) où les ondes courtes firent leur première apparition dans les communications expérimentales à très grande distance jusqu'à ce jour, où leur emploi dans ces communications expérimentales à très grande distance s'est complètement affirmé, en concurrence non seulement avec les ondes longues, mais aussi avec les systèmes de la télégraphie sous-marine.

Tableau des mots transmis par ondes courtes et longues.

Année.	Nombre de mots transmis par ondes longues.	Nombre de mots transmis par ondes courtes.
—	—	—
1923	921.924	—
1924	875.175	120.930
1925	1.627.517	630.780
1926	1.514.574	782.843
1927	428.800	1.884.750
1928	119.583	1.033.988 (jusqu'en juillet.)

Il est à remarquer que le trafic de la station de S. Paolo n'est qu'une partie du trafic commercial avec l'étranger qui en Italie est presque totalement exploité par une société privée, sur l'activité technique de laquelle d'autres pourront donner d'intéressants renseignements.

D'après les enseignements retirés de l'exploitation de la station de S. Paolo, la Marine royale a pu considérablement étendre sa sphère d'activité dans les hautes fréquences en projetant et en construisant dans ses ateliers de nouveaux types d'appareils à onde courte pour le service naval et aérien, soit à grande, soit à moyenne ou à petite distance, à caractère fixe ou de campagne.

6. *Emploi des ondes courtes dans l'expédition polaire.* — C'est avec des appareils de ce type, construits par des spécialistes de l'atelier radio de La Spezia que furent équipées les stations de l'expédition polaire Nobile et particulièrement le dirigeable *Italia*, le navire-base *Città di Milano*, de même que les hydravions type *Savoia* et *Dornier Wall* de l'expédition de secours.

Le tableau qui suit représente le travail total entre la station de S. Paolo et le navire *Città di Milano* depuis avril jusqu'à juillet 1928, c'est-à-dire pendant toute la durée de l'expédition.

Tableau du trafic à onde courte expédié entre S. Paolo et la « Città di Milano » pendant l'expédition polaire.

Mois.	Nombre de mots reçus à S. Paolo de la *Città di Milano*.	Nombre de mots transmis de S. Paolo à la *Città di Milano*.
—	—	—
Avril	32.000	6.578
Mai	48.000	24.534
Juin	316.000	24.000
Juillet	215.000	25.500
	611.000	80.612

7. *Interruption des communications polaires.* — Le service fort intense et ininterrompu pendant toutes les heures du jour entre les stations de S. Paolo et de la *Città di Milano* constitue, à notre avis, le premier exemple de ce qu'on peut obtenir avec les moyens limités dont disposent normalement les navires, lorsqu'on emploie des appareils à très haute fréquence, confiés à un personnel habile.

Seul un service intensif de la sorte a pu mettre en évidence et a permis d'étudier les effets de certaines conditions météorologiques sur les communications à ondes courtes. On reviendra sur cette question après un complet et minutieux examen des importantes données scientifiques recueillies par les membres de l'expédition polaire.

Ce qui nous semble cependant digne d'être dès maintenant signalé, c'est l'influence sur les radiocommunications à ondes courtes d'une aurore boréale exceptionnelle et des phénomènes magnétiques qui l'accompagnèrent.

Alors que les communications radiotélégraphiques entre la station de S. Paolo et la *Città di Milano*, entre cette dernière et la petite station à ondes courtes en possession des naufragés sur le *pack* s'étaient toujours effectuées régulièrement et presque indépendamment des variations atmosphériques, elles eurent un brusque arrêt dans l'après-midi du 7 juillet dernier.

L'impossibilité de la réception dans la zone polaire s'étendait des ondes plus courtes jusqu'aux ondes de 600 mètres environ, qui étaient sensiblement affaiblies et avec des signaux coupés, de sorte que les communications à onde moyenne entre les îles Svalbard et la Scandinavie furent aussi interrompues.

D'après les informations que nous possédons à présent, on peut déduire que dans tout le Nord de la Scandinavie la bourrasque magnétique avait troublé toutes les communications radiotélégraphiques ainsi que celles par téléphonie avec fil.

En Allemagne, le fonctionnement des stations radio à ondes courtes entre l'Europe et l'Amérique, et en d'autres directions aussi, fut tout à fait paralysé dans toute la gamme d'ondes courtes entre 14 et 30 mètres. On remarqua également que la perturbation du 8 juillet 1928 a été la plus forte que l'Observatoire magnétique de Potsdam ait enregistrée dans ces trois dernières années.

D'après les remarques des techniciens allemands, la perturbation principale, qui fut accompagnée par deux autres, une précédente et une suivante, commença le 7 juillet, à minuit du T. M. G. et dura jusqu'à 22 heures T. M. G. environ du jour suivant (*).

Pendant cette période, les transmissions de l'Amérique du Nord ainsi que celles de la *Città di Milano* furent tout à fait imperceptibles en Allemagne. Les ondes nocturnes, au contraire, étaient interceptées faiblement pour des temps assez courts; mais les ondes du groupe de 22 mètres étaient absolument imperceptibles. Les transmissions entre Berlin et l'Amérique du Sud purent s'effectuer, quoique faiblement et seulement de nuit, tandis que les transmissions de l'Est furent seulement quelque peu dérangées, notamment les communications entre l'Allemagne et le Siam.

Aux États-Unis d'Amérique le phénomène de l'aurore boréale fut entièrement visible dans la partie nord du ciel de Washington, de 22 heures à minuit le 7 juillet. Au dire des spectateurs qui l'observèrent, le phénomène ressemblait à un grand nombre de réflecteurs électriques braqués vers le haut, pendant que dans la partie orientale du ciel on apercevait une lueur rouge, qui donnait l'idée d'une forêt en flammes.

Pendant cette période les communications à très haute fréquence effectuées habituellement par la station centrale du « *Navy Department* » (N. A. A.), y comprises celles avec la station de S. Paolo, furent virtuellement impossibles, parce que les signaux étaient tout à fait imperceptibles. Quelques communications purent être maintenues sur les fréquences intermédiaires, celles à basse fréquence (onde longue) ne purent être effectuées qu'avec une extrême difficulté.

En Italie, au contraire, les seules communications à onde courte interrompues furent celles provenant de la région polaire et de l'Amérique du Nord, tandis que l'on put maintenir sans aucune difficulté le reliement à très haute fré-

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(*) Ces observations concordent en général avec celles de quelques observateurs français, à ce qu'on peut lire dans le numéro d'août 1928, p. 363, de *L'Onde électrique*.

quence avec l'Extrême-Orient, avec Massaua, avec Mogadiscio et avec des navires en haute mer.

Pour transmettre les télégrammes à la *Città di Milano* il fallut sur sa requête, faire fonctionner l'arc Poulsen avec onde de 10,750 mètres. Malgré cela, les communications ne s'effectuèrent qu'avec difficulté.

Il est intéressant de remarquer que le phénomène de la disparition des signaux, qui fut complet dans les trois jours du 7 au 9 juillet, cessa graduellement en suite, témoignant ainsi que l'immense banc d'espace ionisé, qui constituait la barrière, allait en se dissolvant progressivement.

L'influence sur les radiocommunications s'accentue davantage à mesure que l'on s'approche de la zone polaire, et le phénomène est plus sensible quand le parcours des ondes est perpendiculaire à la direction du champ magnétique terrestre.

D'ailleurs, si la campagne de la *Città di Milano* dans les mers Arctiques a donné une bonne occasion d'étudier l'influence des aurores boréales sur les communications à ondes courtes, d'autres aussi avaient observé l'influence de ces météores sur les communications radiotélégraphiques.

Il est intéressant de citer les constatations de M. Arnold lesquelles correspondent parfaitement avec celles que nous avons faites. Dès 1924, en effet, M. Edward Arnold put constater, à l'occasion de mesures de courants produits par les aurores boréales dans les câbles sous-marins et dans les lignes télégraphiques terrestres, que lorsque l'aurore atteignait une intensité considérable, fût-elle visible ou non — sa présence était immédiatement révélée par un rapide affaiblissement des signaux, comme si ceux-ci avaient été étouffés. Si le phénomène persistait sans interruption, on avait l'impression qu'un voile de silence s'était étendu sur les transmissions. L'effet était encore plus remarquable sur les communications à ondes persistantes à grandes distances, mais aussi les signaux des stations commerciales, qui travaillent normalement sur l'onde de 600 mètres, en étaient considérablement affaiblies (cf. *The Wireless Age*, de février 1924, vol. XI).

Il est certain qu'on pourra obtenir d'autres éclaircissements sur cet important phénomène quand on sera en possession du recueil des mesures et des observations magnétiques faites aux îles Svalbard.

⁂

Les radiocommunications sont aujourd'hui, à notre avis, définitivement orientées vers l'emploi de fréquences d'émissions supérieures à 3,000 Kc/s, qui constituent désormais les gammes de fréquence les plus indiquées pour le développement des services à très grande distance, soit qu'ils soient fixes ou bien mobiles.

Même dans les services à moyenne et à petite distance, les très hautes fréquences, avec la graduelle amélioration des appareils émetteurs et récepteurs, et avec le meilleur entraînement du personnel, sont destinées à substituer les fréquences plus basses, qui exigent l'emploi de mécanismes plus coûteux et de grandes antennes et qui peuvent être difficilement émises avec un haut rendement.

Les très hautes fréquences ont permis enfin de vaincre cet obstacle des perturbations atmosphériques qui semblait autrefois insurmontable, en donnant par là, la possibilité à la radiotélégraphie de réaliser des communications sûres et constantes, et de rivaliser avec les moyens de communication plus vieux et jusqu'à présent jugés plus sûrs, tels que les lignes et les câbles télégraphiques sous-marins.

Rome, le 6 septembre 1928.

A la suite de la communication de MM. Pession et Montefinale, M. Vanni fait remarquer que les résultats obtenus par la Marine italienne à l'occasion de l'expédition Nobile, constituent une preuve nouvelle de l'action puissante exercée par la télégraphie sans fil non seulement au point de vue scientifique et technique, mais aussi au point de vue humanitaire et social. Sans la grande invention de Marconi, les naufragés de cette expédition polaire auraient été isolés du monde entier dans les sombres régions de la zone polaire, et on n'aurait pas eu la possibilité de leur apporter des secours!

A NOTE ON THE DIRECTIONAL OBSERVATIONS OF GRINDERS IN JAPAN.

by EITARO YOKOYAMA and TOMOZO NAKAI,

Electrotechnical Laboratory, Ministry of Communications, Tokyo.

In the last General Assembly of the Union, a paper entitled *The Directional Observations on Atmospherics in Japan* (*) was presented by the authors, and the following conclusions had been arrived at by the series of observations.

1. No appreciable change had been found in the observed directions of the atmospherics by the variation of wave lengths which lie between 10,000 and 20,000 metres.

2. On the diurnal observations from 7 A. M. to 9 P. M. no appreciable regular change had been noticed in the observed directions of atmospherics during day time. Through some expected variations had, in general, been noticed at sunrise, sunset and night time, they had not been so remarkable as in the case of signal observations.

3. The directions of clicks had been obviously different from those of grinders, which seems to indicate that the seat of clicks differs from those of grinders.

4. The diurnal variation had been much greater in the directions of clicks than in those of grinders. This seems to indicate that the seat of clicks lies nearer to the observed region than those of grinders, if the seats of both kinds of atmospherics might be assumed to have nearly equal areas. Judged from the great differences in the intensities as well as in the nature of tones of clicks and grinders, this assumption may be considered to be probable.

5. The directions of clicks had shifted from

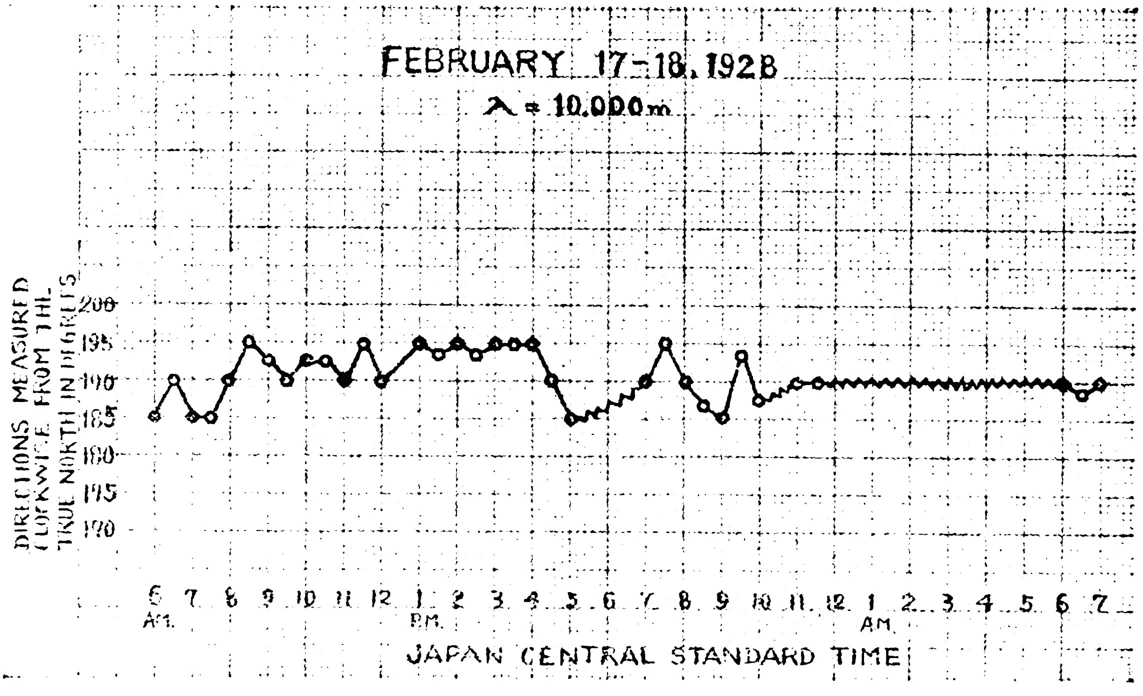

FIG. 1.

(*) Vol. I, fasc. 1, p. 74.

nearly South toward West as the season advanced from winter to summer, while those of grinders had remained unchanged.

6. In summer, the clicks, which seem to originate from the mountainous regions of Japan, are most prevalent, while grinders probably come always from a tropical region such as the Dutch East-Indies.

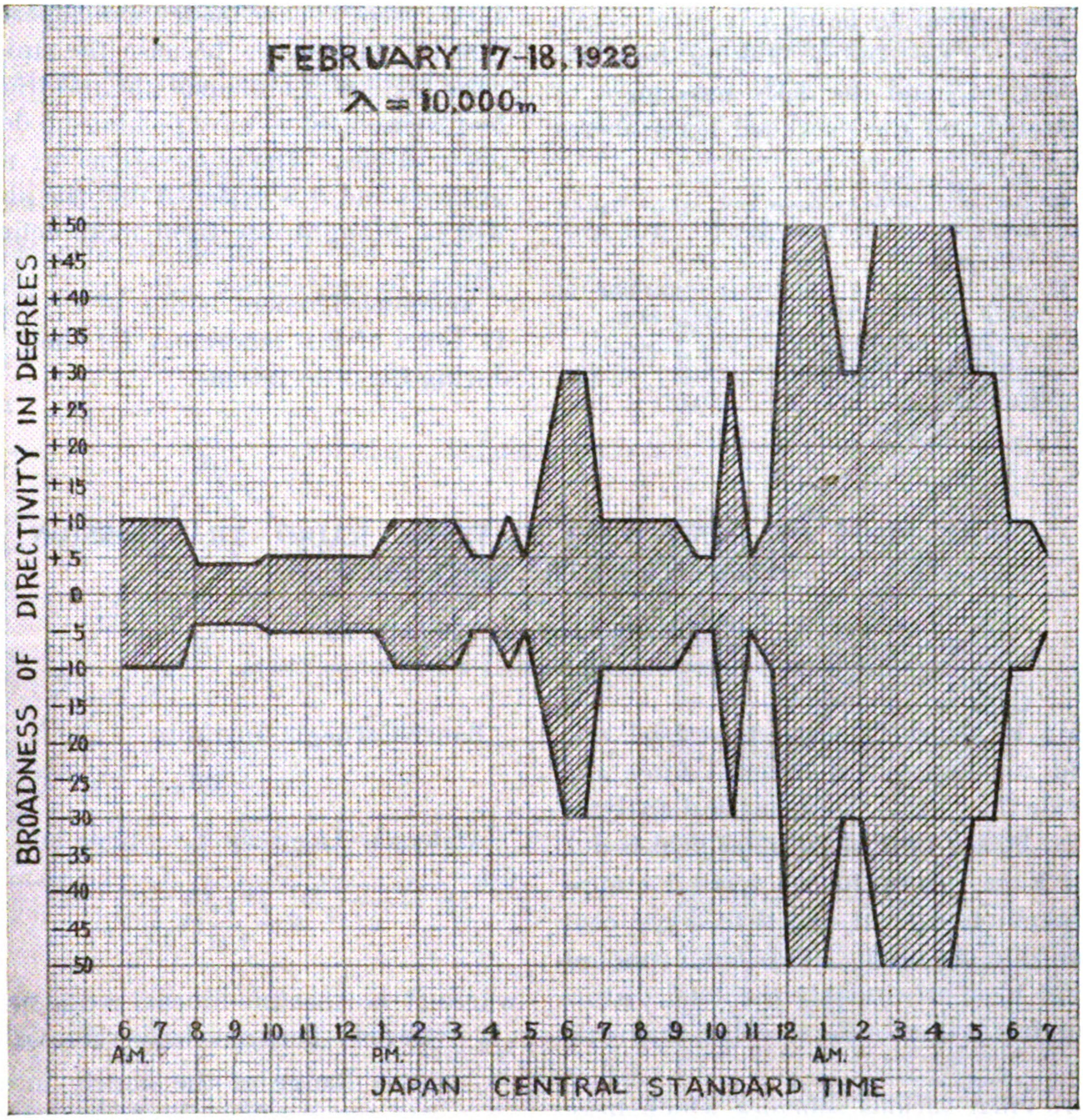

FIG. 2.

These were the results obtained from the observations over a period from February to July, 1927. The experiments were further continued and it was recognized that the same conclusions still hold good, except in the night observations of grinders.

During the experiments, ten courses of 24 hour observations were made, covering all the seasons of the year. Though no other particular phenomena were noticed in the observations of clicks, it was remarkably found in those of grinders; on the contrary, that the directive property became indistinct or disappeared at night. One example of directional variations (wave length 10,000 metres) is shown in figure 1 in which the zigzag lines indicate the durations of directivity fading, and in figure 2 which illustrates the change in the broadness of directivity in the same observation as shown in figure 1. In other 24 hour observations, the general tendencies of the variations were quite similar, though the times at both extremities of the fading bands of directivity shifted by a few hours according to the dates.

It is in general believed that the origins of long wave atmospherics, as received in both England and the United States, are mainly in the lands situated in the Tropical Zone (*). The grinders as received in Japan had also been indicated by the authors to be of a tropical origin such as the Dutch East-Indies. Taking the above into consideration and the daily movement of the illuminated and the darkened hemispheres into account, the atmospherics originating at the tropical region in America seem very probable to be received in Japan as grinders early at night and those in Africa late at night, while those in the Dutch East-Indies may be received for all the time of day and night. Thus the grinders coming from other parts than the Dutch East-Indies seem to have made them appearently non-directive at night, because the unidirectional combination of antennas was not tried, a single loop being used as wave picking-up device in the observations. The observations are now still in progress and it is expected that the phenomenon will be brought into light more definitely later on.

Acknowledgement is due to C. Asakawa and T. Takei of this laboratory for their assistances during the observations.

June, 1928.

(*) Lloyd Espenschied, C. N. Anderson and Austin Bailey, Transatlantic Radio Telephone Transmission. (*P. I. R. E.*, vol. XIV, p. 7, February, 1926.)

— R. A. Watson Watt, The directional Recording of atmospherics. (*J. I. E. E.*, vol. LXIV, p. 596, May, 1926.)

— L. W. Austin, Direction determinations of atmospheric disturbances on the Isthmus of Panama. (*P. I. R. E.*, vol. XIV, p. 373, June, 1926.)

CORRELATION OF LONG WAVE DAYTIME RADIO TRANSMISSION WITH MAGNETIC DISTURBANCES

by T. MINOHARA and T. INOUYE.

Naval Experimental and Research Establishment, Tokyo.

According to Gauss's theory, terrestrial magnetic field is composed of internal force and forces outside the earth. Mathematical analyses indicate that 96 per cent of the total field is due to internal force, partly to the vertical atmospheric conduction current and 2 to 3 per cent to forces outside the earth. This latter amount is equivalent to approximately the total disturbance occurring at time of the so-called magnetic storms.

Below are cited various schemes which have been proposed for indicating the magnetic character.

Chree-Kew Observatory :

$$R^2 = \frac{1}{100}(R_D^2 + R_H^2 + R_Z^2).$$

Schmidt-Potsdam Observatory :

$$A = A_D + A_H + A_Z.$$

Van Dijk-De Bilt Observatory :

$$R = R_D + R_H + R_Z.$$

Bauer-Carnegie Institute :

$$HR_H.$$

Anderson-American Telephone and Telegraph Co.

$$V = \frac{1}{100}(V_H + V_Z).$$

where R = Absolute diurnal range or difference between daily values.
A = Range of the hourly mean values.
H = Horizontal intensity.
Z = Vertical intensity.
D = Declination.
V = The sum of hourly variations for 24 hours.

All of the expressions above mentioned are denoted by the variations in components of earth's magnetism.

From Gauss's point of view, treating the earth's magnetic field as it is composed of internal force and external forces and also assuming that its variations are caused mainly by the external forces, denoting them as vectors, if we express the internal force or the force stored in the earth as O*m* in figure 1 and actual magnetic force at a given time as O*a*, then we can express the external force at that time by *ma*. Accordingly, if the earth's magnetism is changed from *oa* to *ob* then the external force is to be expressed by *mb*.

The magnitude of the external force *ma* should be

$$\left(\overline{m_1a_1}^2 + \overline{m_2a_2}^2\right)^{\frac{1}{2}}$$

but for the sake of simplicity we take $(m_1a_1 + M_2a_2)$ for it. Thus the correlation of radio receiving strength with magnetic character is obtained.

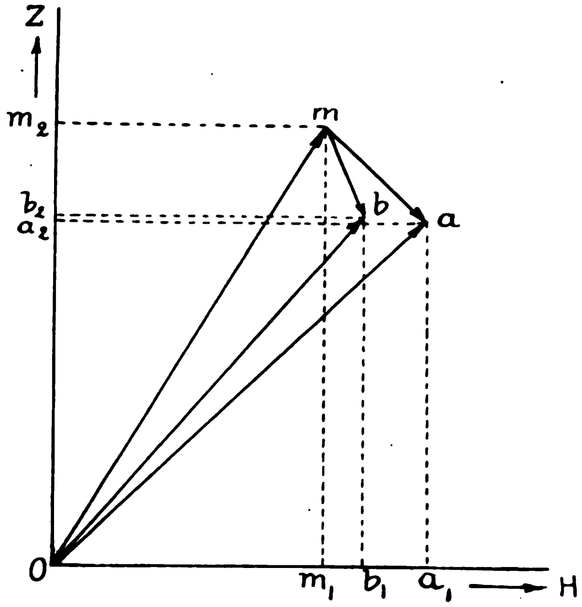

FIG. 1.

Diurnal mean value of earth's magnetism are those observed at Kakioka near Tokyo by central Meteorological Observatory. The daily values of signal strength are those, observed and measured by G. Ōsawa and S. Ōno at Tokyo at 9 A. M. local time of time signal from Pearl Harbour (*) (26.1 K.C.). As the radio waves sent out from Pearl Harbour at that time of a day will travel the entire transmission path in daylight,

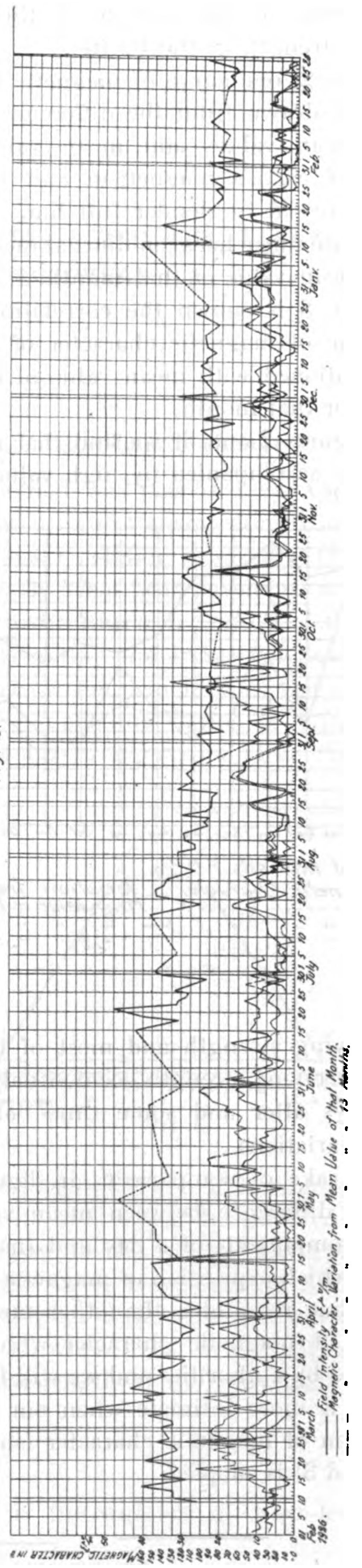

Fig. 2.

(*) Report submitted to the last assembly of U. R. S. I.

the data may be duly said to be the daytime receiving strength in the Pacific.

In figure 2, one curve of magnetic character (— - —) is drawn from the difference between diurnal mean values and mean value of 13 month's of earth's magnetism and the other curve (expressed in slender full line) is drawn from the difference between diurnal mean values and the mean value of that month.

In figure 3 is shown the correlation of the mean value of magnetic character of a month above mentioned with mean value of receiving strength for that month.

From figures 2 and 3, we find that magnetic variation is accompanied by high value of daylight receiving strength and most of the high values of receiving strength occur usualy within several days after and some time before the magnetic variations.

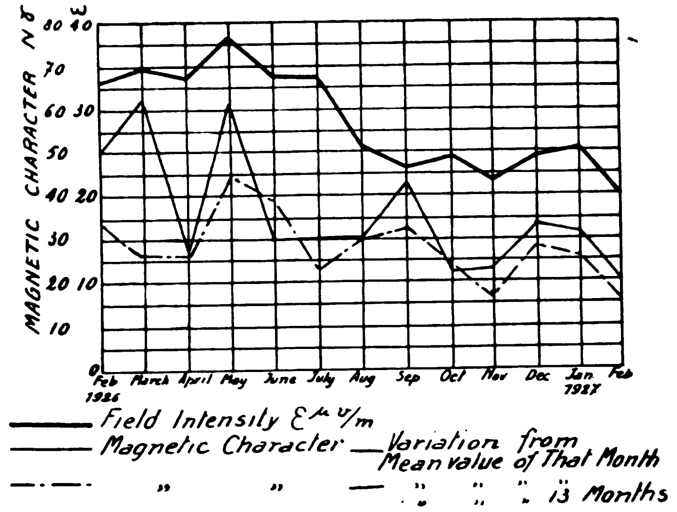

FIG. 3.

For the sake of comparison, in figure 4 is shown the difference between mean values of magnetic components of a day and that of the next day : which expression of magnetic character somewhat resembles the other method of expression of magnetic character which have been devised by authorities and we will find that correlation is more intimate when our method of expression of magnetic character (shown in figures 2 and 3) is adopted.

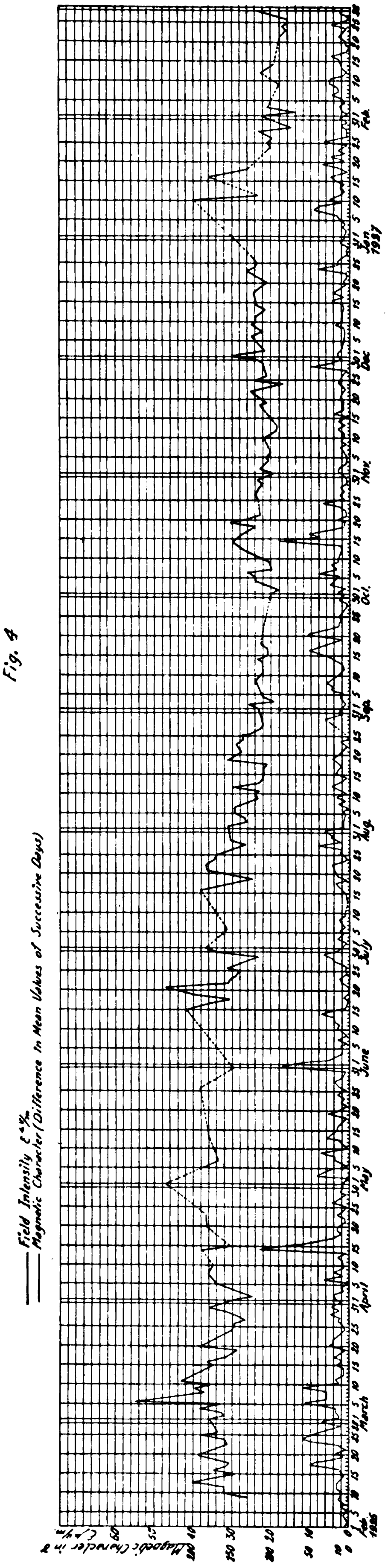

Fig. 4

SOME NOTES ON WIRELESS METHODS OF INVESTIGATING THE ELECTRICAL STRUCTURE OF THE UPPER ATMOSPHERE

by E. V. APPLETON, F.R.S.

(Great Britain.)

ABSTRACT. — Various direct wireless methods of measuring the « effective » height of the atmospheric ionized layer are discussed and compared. For a layer of horizontal statification, and under conditions for which the influence of the earth's magnetic field may be neglected, the general equivalence of the quantities measured by the various methods is demonstrated. The effective height in such cases is shown to be greater than the maximum height reached by the atmospheric ray. Proposals for using these methods to obtain information concerning the gradient of ionization in the layer are put forward.

1. Introduction.

Within the last few years various direct wireless methods have been proposed for determining the « effective » height of the ionized layer in the upper atmosphere. There is a somewhat wide divergence in the experimental values obtained by these methods so that it is pertinent to inquire what significance should be attached to the term « effective » in the various cases and also to ascertain whether any agreement is to be expected if the experiments are conducted under similar conditions of wave-length, location, etc. It is easily seen that, if we are dealing with cases of true reflection at a very sharply bounded and higly conducting layer, the track of the atmospheric waves being entirely in unionized air, all the methods should give the same result. If, however, the waves are returned to the ground by the process of « ionic refraction » (*) in a dispersive medium a more detailed examination is necessary before any corresponding statement can be made. The various methods are therefore discussed in greater detail below.

2 (*a*). Wave-length change method.

This method was proposed by Appleton and Barnett and used on transmissions from the Bournemouth B.B.C. station received at Oxford (**). More recently it has been developed at the Peterborough Radio Research Station of the Department of Scientific and Industrial Research.

To illustrate the principles of this method let us consider a sending station at A (see Fig. 1) sending to a receiving station at E. In the ideal case of an ionized layer of horizontal stratification two sets of waves are received at E, the ground waves travelling direct along AE and the atmospheric waves travelling via ABCHE. Let the optical path difference between these two tracks be D, where D is, in general, a function of the wave-length of the radiation. We then have

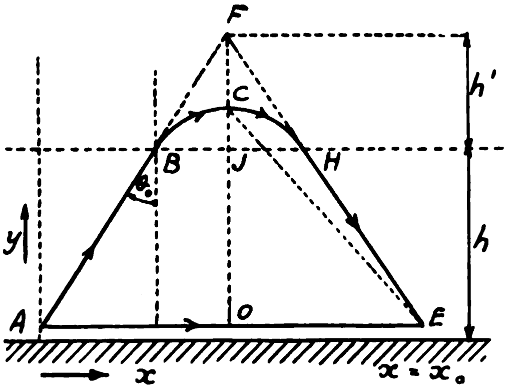

FIG. 1.

$$n = \frac{D}{\lambda} \tag{1}$$

where n is the number of wave-lengths the

(*) *Vide* Eccles, *Proc. Roy. Soc.* A, **87**, 79 (1912) and Larmor, *Phil. Mag.* (6), **48**, 1025 (1924).

(**) *Nature*, March 7, 1925.

atmospheric waves are behind the ground waves at the point E and λ is the wave-length in air. We have, further,

$$D = \int_{ACE} \mu ds - AE, \qquad (2)$$

where μ is the refractive index at any point and ds is an element of length of the atmospheric ray path (*).

The experimental procedure in the wave-length change method consists in measuring the variation in n (as shown by the signal current maxima and minima experienced at E) when λ is continuously varied through a small range. From (1) the variation in n is given by

$$\delta n = -\frac{D}{\lambda^2}\delta\lambda + \frac{1}{\lambda}\delta D. \qquad (3)$$

It has been usual to neglect the variation of D in (3) and consider $\lambda^2 \frac{\delta n}{\delta \lambda}$ as the « equivalent path difference » between atmospheric and ground ray paths from which, by simple triangulation, the « equivalent height » of the deviating layer was obtained. The justification of the use of the term « equivalent height » in this connection will be seen in what follows.

It is shown in Appendix I that for a variation in optical path due to a finite change of wave-length such as we are considering, we have

$$\delta D = \delta \int_{ACE} \mu ds = \int_{ACE} \frac{\partial \mu}{\partial \lambda} ds \, \delta\lambda, \qquad (4)$$

so that, combining with (2) and (3) we have

$$-\lambda^2 \frac{\delta n}{\delta \lambda} = \int_{ACE} \mu ds - \lambda \int_{ACE} \frac{\partial \mu}{\partial \lambda} ds - AE. \qquad (5)$$

But, from the usual relation between group velocity U, refractive index and wave-length we have, as show in Appendix II,

$$c \int \frac{ds}{U} = \int \mu ds - \lambda \int \frac{\partial \mu}{\partial \lambda} ds, \qquad (6)$$

where c is the velocity of radiation in free space, so that from (5) and (6) we have

$$\lambda^2 \frac{\delta n}{\delta \lambda} = c \int_{ACE} \frac{ds}{U} - AE, \qquad (7)$$

where the negative sign of the experimentally determined quantity $\lambda^2 \frac{\delta n}{\delta \lambda}$ has been omitted since δn is negative for an increase of wave-length. We thus see that the « equivalent path difference » is equal to the product of the velocity in free space multiplied by the temporal retardation of a signal traversing the atmospheric path with its appropriate group velocity compared with a signal traversing the ground path. This is quite a different quantity from the actual path difference obtained from (3) by neglecting δD for which approximation we should write, using (2),

$$\lambda^2 \frac{\delta n}{\delta \lambda} = \int_{ACE} \mu ds - AE. \qquad (7a)$$

In the case in which the influence of the earth's magnetic field may be neglected (e.g. with short waves) it is easy to show that $U = c\mu$ so that, for such conditions the optical path of the atmospheric ray would be $\int \mu ds$ while the equivalent path would be $\int \frac{ds}{\mu}$.

It should be mentioned here that, strictly speaking, we should also write

$$\text{Ground Path} = \int_{AOE} \mu ds, \qquad (8)$$

so that for a variation in wave-length

$$\delta(\text{Ground Path}) = \int_{AOE} \frac{\partial \mu}{\partial \lambda} ds \, \delta\lambda, \qquad (9)$$

leading ultimately to the general result

$$\lambda^2 \frac{\delta n}{\delta \lambda} = c \int_{ACE} \frac{ds}{U} - c \int_{AOE} \frac{ds}{U'}, \qquad (10)$$

where U′ is the group velocity of the waves along the ground. It seems quite possible that U′ may differ appreciably from c when very short waves are used.

2 (*b*). Angle of incidence method.

This method was proposed by Appleton and Barnett (*) and used at Cambridge to determine the angle of incidence of down-coming waves emitted by the London B.B.C. transmitter. It has also been used by Smith-Rose and Bar-

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(*) The possibility of the dispersion of the ground waves is discussed below.

(*) *Electrician*, April 3, p. 398, 1925 and *Proc. Roy. Soc.* A, **109**, 621 (1925).

field (*). in a comprehensive study of downcoming waves received from various stations. When the angle of incidence is known the « effective height » of the layer deviating the waves is found by simple triangulation. This quantity would correspond to FO in figure 1.

In the general case of magneto-ionic refraction in which the influence of the earth's magnetism is taken into account it is difficult to interpret these experiments much further. If, however, we neglect this influence and also assume that the layer is horizontally stratified a correlation with the wave-length change method may be effected. Since, in such a case, the experimentally determined angle of incidence θ_0 at the ground is also equal to the angle of incidence at the layer we may write

$$\mu \sin \theta = \sin \theta_0, \tag{11}$$

where θ is the angle the atmospheric ray makes with the vertical at any point at which the index of refraction of the medium is μ. Also, as before, we have

$$U = c\mu. \tag{12}$$

Thus, since $dx = ds \sin \theta$ for the atmospheric ray, we have, using (11) and (12)

$$c\int \frac{ds}{U} = \int \frac{ds}{\mu} = \int \frac{dx}{\sin \theta_0} = (AF + FE). \tag{13}$$

The quantity $c\int \frac{ds}{U}$, as Breit and Tuve (**) first pointed out, is therefore equal to the actual path AFE (see fig. 1). We thus see that, in the case of short waves, the equivalent path of the atmospheric waves measured by the wave-length change method is equal to the effective path obtained by simple triangulation using the angle of incidence of the waves as measured at the ground. Thus both methods (*a*) and (*b*) give the height FO which is greater than the true height CO (see fig. 1).

2 (*c*). Group-retardation method.

This method was first proposed and used by Breit and Tuve (***) who used a transmitter sending out short pulses of radio-frequency energy and measured the time interval Δt between the arrival of signal pulses received via the ground and via the atmosphere.

For such a case, using again figure 1 we may write, simply,

$$\Delta t = \int_{ACE} \frac{ds}{U} - \int_{AOE} \frac{ds}{U'}, \tag{14}$$

from which the general equivalence of what is measured in the wave-length change method and in the group retardation method is at once apparent.

It has, however, been pointed out to me by Mr. J. A. Ratcliffe that (14) applied to the group-retardation method requires qualification, since the component frequencies of the group do not follow the same path. The problem is therefore a little more complicated than that contemplated in the ordinary discussions of group velocity in which the frequency components (usually two) of the group travel along the same (usually straight) path. The following justification of the applicability of (14) is therefore offered. The case of a particularly simple type of group transmission which has not yet been tried in practice is first examined. The discussion of the actual type of group transmission used by Breit and Tuve then follows.

Let us consider the simplest case of the transmission of a group of waves and imagine two sets of waves, the frequencies of which differ only slightly, emitted by a sending station. If the angular frequencies of the waves are $p - \delta p$ and $p + \delta p$ beats of frequency $\frac{\delta p}{\pi}$ will be produced when the waves travel in unionized air along the same track. For both sets of waves to arrive at the same receiving station (*e.g.* E in fig. 1) they must set out from the sending station along slightly different directions because of the dispersion in the ionized layer. To allow for the difference in frequency and for the difference in the optical paths of the two components we say that the received signal amplitude is proportional to

$$\cos(p - \delta p)\left(t - \frac{P - \delta P}{c}\right) + \cos(p + \delta p)\left(t - \frac{P + \delta P}{c}\right), \tag{15}$$

or to

$$2 \cos p\left(t - \frac{pP}{c}\right) \cos\left(\frac{\delta p\, P}{c} + \frac{p\delta P}{c} - t\delta p\right), \tag{16}$$

(*) *Proc. Roy. Soc.* A, **110**, 580 (1926) and **116**, 682 (1927).

(**) *Physical Review*, **28**, nº 3, 571 (Sept. 1926).

(***) *Loc. cit.*

where P is the optical path of the atmospheric ray for angular frequency p. The expression for the received signal amplitude represents a high frequency oscillation of slowly varying amplitude. The particular maximum amplitude emitted by the sending station when t and P are zero is reproduced again at the receiver after a time t given by

$$\frac{\delta p \mathrm{P}}{c} + \frac{p \delta \mathrm{P}}{c} - t\delta p = 0,$$

or by

$$ct = \int \mu ds + p\frac{\delta}{\delta p}\int \mu ds, \tag{17}$$

$$= \int \mu ds - \lambda\frac{\delta}{\delta\lambda}\int \mu ds. \tag{18}$$

Now from Appendix I we have

$$\frac{\delta}{\delta\lambda}\int \mu ds = \int \frac{\partial\mu}{\partial\lambda} ds.$$

Thus (18) becomes

$$ct = \int \mu ds - \lambda \int \frac{\partial\mu}{\partial\lambda} ds \tag{19}$$

$$= c\int \frac{ds}{\mathrm{U}}. \tag{20}$$

We thus see that a particular beat maximum emitted by the sending station is produced again at the receiving station after a time $\int \frac{ds}{\mathrm{U}}$ where U is the group velocity for the mean frequency. The use of (14) is therefore justified even though the two component frequenties have followed slightly different tracks.

To measure the group retardation in such an experiment as has been suggested above, the down-coming waves could be received on a suppressed ground ray system and the high frequency oscillations produced rectified, thus transforming the beats into combination tones. The phase of the combination tone received via the atmosphere could be compared with that of the combination tone received via the ground waves and, from a knowledge of the beat frequency, the retardation found.

An imaginary experiment shows even more closely the essential equivalence of the wave-length change method and the particular type of ground retardation method described immediately above. Let us suppose that one of the emitted wave-lengths is maintained constant and the other made gradually different so that the beat frequency increases from zero. The phase difference between the beat amplitudes received via the atmosphere and via the ground will gradually increase. Let us now suppose that when the wave-lengths differ by $\delta\lambda$ the phase difference is Φ where Φ is $2\pi n'$. The group retardation Δt is then evidently $n't'$, where t' is the time of one beat. But t' is equal to $\frac{\lambda^2}{c\delta\lambda}$, so that, using again figure 1, we have

$$\Delta t = \int_{\mathrm{ACE}} \frac{ds}{\mathrm{U}} - \int_{\mathrm{AOE}} \frac{ds}{\mathrm{U}'} = n'\left(\frac{\lambda^2}{c\delta\lambda}\right). \tag{21}$$

But if the two wave-lengths emitted by the sending station had been the initial and final wave-lengths during a wave-length change experiment we should have from (10)

$$\lambda^2\frac{\delta n}{\delta\lambda} = \int_{\mathrm{ACE}} \frac{ds}{\mathrm{U}} - \int_{\mathrm{AOE}} \frac{ds}{\mathrm{U}'}, \tag{22}$$

so that

$$n' = \delta n.$$

Thus the number of « fringes » measured in the wave-length change method is equal to the number of beats the atmospheric ray is behind the ground ray when the beats are produced by the simultaneous emission of the initial and final wave-lengths used.

The extension to the case of pulses of radio-frequency waves as actually used by Breit and Tuve follows on similar lines. Let us suppose that the group may be represented by the sum of a large number of sinusoidal vibrations the frequencies of which differ only slightly from $\frac{p}{2\pi}$. The disturbance arriving at the receiving station may then be represented by

$$\Sigma a \cos (p + \delta p)\left(t - \frac{\mathrm{P} + \delta \mathrm{P}}{c}\right),$$

which is equal to

$$\cos p\left(t - \frac{\mathrm{P}}{c}\right) \Sigma a \cos\left(t\delta p - \delta p\frac{\mathrm{P}}{c} - p\frac{\delta \mathrm{P}}{c}\right)$$
$$- \sin p\left(t - \frac{\mathrm{P}}{c}\right) \Sigma a \sin\left(t\delta p - \delta p\frac{\mathrm{P}}{c} - p\frac{\delta \mathrm{P}}{c}\right).$$

We thus get the reproduction of the original wave-form (*i. e.* the group is received) at the receiver when

$$t\delta p - \delta p\frac{\mathrm{P}}{c} - p\frac{\delta \mathrm{P}}{c} = 0,$$

or when

$$t = \frac{1}{c}\left(\int \mu\, ds + p\frac{\delta}{\delta p}\int \mu\, ds\right). \tag{23}$$

But (23) is identical with (17) which was shown to lead to

$$t = \int \frac{ds}{\mathrm{U}}. \tag{24}$$

In this case t is the time of transmission of the group through the atmosphere and U the group velocity of the mean frequency. In the actual experiment of Breit and Tuve the use of (14) may therefore be justified even when the different components of the group follow different tracks in the upper atmosphere.

It will be seen that for the measurement of the group-retardation it is not necessary to send out « chopped » (*) signals like those used by Breit and Tuve. A sinusoidally-modulated wave would suffice for receiving stations at which the ground waves are strong. In the case of short waves and fairly long transmission distances the ground waves would be strongly absorbed and thus of negligible strength at the receiver. In such cases the modulation signal or the « chopped » signals of Breit and Tuve could be transmitted simultaneously along the ground by a much longer wireless wave-length or possibly by telephone.

Summarizing the results of this section we may say that :

1. The wave-length change method and the group-retardation method measure the same quantity $\left(\text{i. e. } c\int \frac{ds}{\mathrm{U}} \text{ for the atmospheric waves}\right)$.

2. In cases for which the effect of the earth's magnetic field is negligible and the layer is horizontally stratified, the above-mentioned methods, together with the angle of incidence method, give us the equivalent height FO in figure 1. The equivalent height is greater than the actual maximum height reached by the atmospheric waves.

3. Some special ionization gradients.

It is instructive to consider some of the questions discussed above for some particular types of ionization gradients in the layer.

Let us suppose (see figure 2 in which the lettering is the same as in figure 1) that a ray enters the layer at O, and that the gradual deviation of it is brought about by the gradual reduction of the refractive index (due to the increasing ionization) experienced as it penetrates the layer. Consider any point P on the path of the ray and let the tangent to the path at that point make an angle θ with the vertical (i. e. with the y axis in the figure). We then have, as before,

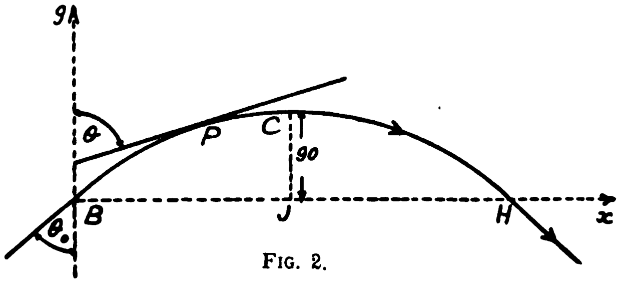

Fig. 2.

$$\mu \sin\theta = \mu_0 \sin\theta_0 = \sin\theta_0, \tag{25}$$

where μ is the refractive index at the point P and μ_0 $(=1)$ is the refractive index of the unionized air. θ_0 is the angle of incidence at the layer. The refractive index μ is considered as being independent of x and dependent only on y and the wave-length.

Since

$$\tan\theta = \frac{dx}{dy},$$

and

$$ds = \sqrt{1 + \tan^2\theta}\, dy,$$

the optical path in the medium is given by

$$\int \mu\, ds = 2\int_0^{y_0} \mu\sqrt{1 + \left(\frac{dx}{dy}\right)^2}\, dy$$

$$= 2\int_0^{y_0} \frac{\mu^2}{\sqrt{\mu^2 - \sin^2\theta_0}}\, dy, \tag{26}$$

where $\mu = f(y, \lambda)$ and $\sin\theta_0 = f(y_0, \lambda)$.

Correspondingly we have for the «equivalent» path

$$\int \frac{ds}{\mu} = 2\int_0^{y_0} \frac{dy}{\sqrt{\mu^2 - \sin^2\theta_0}}. \tag{27}$$

(*) A simple method of obtaining these short trains of oscillations is to use a transmitter with a high grid leak the circuit being similar to that used for producing the unidirectional cathode-ray oscillograph time base. *Vide Proc. Roy. Soc.* A, **111**, 672 (1926).

The above expressions have been derived on the assumption that μ is a single-valued function of position for constant wave-length and so the argument only applies to the case in which the influence of the earth's magnetic field is negligible. We therefore consider the case as applying to the propagation of short waves. For this reason we may take simple types of variation of the refractive index such as

$$\mu^2 = 1 - \alpha y \qquad \text{Case } (\alpha)$$

and

$$\mu^2 = 1 - \beta y^2. \qquad \text{Case } (\beta)$$

Case (α) corresponds to a gradient in which the ionization varies directly with the height above the lower boundary of the layer, while Case (β) corresponds to ionization varying as the square of the height. By substituting for μ^2 in (25) and (26) and integrating it is possible to arrive at the following results for the two cases.

Case (α). $\mu^2 = 1 - \alpha y$:

$$\left.\begin{array}{l}
\text{Optical path in the layer} \\
\quad = \displaystyle\int \mu\, ds = \frac{4}{\alpha}\cos\theta_0 - \frac{8}{3\alpha}\cos^3\theta_0 \\
\text{Equivalent path in the layer} \\
\quad = \displaystyle\int \frac{ds}{\mu} = \frac{4}{\alpha}\cos\theta_0 \\
\text{Horizontal distance in the layer } (BH \text{ in figure}) \\
\quad = \displaystyle\frac{4}{\alpha}\sin\theta_0 \, . \cos\theta_0 \\
\text{Maximum height in the layer } (CJ. \text{ in figure}) \\
\quad = \displaystyle\frac{\cos^2\theta_0}{\alpha}.
\end{array}\right\} \quad (28)$$

Case (β). $\mu^2 = 1 - \beta y^2$:

$$\left.\begin{array}{l}
\text{Optical path in the layer} \\
\quad = \displaystyle\int \mu\, ds = \frac{\pi}{2\sqrt{\beta}}(1 + \sin^2\theta_0) \\
\text{Equivalent path in the layer} \\
\quad = \displaystyle\int \frac{ds}{\mu} = \frac{\pi}{\sqrt{\beta}} \\
\text{Horizontal distance in the layer} \\
\quad = \displaystyle\frac{\pi \sin\theta_0}{\sqrt{\beta}} \\
\text{Maximum height in the layer} \\
\quad = \displaystyle\frac{\cos\theta_0}{\sqrt{\beta}}.
\end{array}\right\} \quad (29)$$

Now in attempting to verify for the above examples that the equivalent path $\int \frac{ds}{\mu}$, which is the quantity measured in the group-retardation method, is the same as the quantity

$$\int \mu ds - \lambda \frac{\delta}{\delta\lambda} \int \mu ds$$

measured in the wave-length change method, we have to consider the problem as a whole and recognize that both the angle of incidence at the layer and the track in and out of the layer all vary when we vary the wave-length. Let us therefore consider the complete problem of a layer situated at a distance h above the ground (see fig. 1) and take the case of transmission between two points a distance d (*i. e.* AE in fig. 1) apart. For stationary conditions of wave-length we can write in the two cases :

Case (α):

$$\left.\begin{array}{l}
\text{Total optical path of atmospheric ray} \\
\quad = \displaystyle\int \mu\, ds = \frac{2h}{\cos\theta_0} + \frac{4}{\alpha}\cos\theta_0 - \frac{8}{3\alpha}\cos^3\theta_0 \\
\text{Total equivalent path of atmospheric ray} \\
\quad = \displaystyle\int \frac{ds}{\mu} = \frac{2h}{\cos\theta_0} + \frac{4}{\alpha}\cos\theta_0 \\
\text{Path of ground ray} \\
\quad = d = 2h\tan\theta_0 + \displaystyle\frac{2}{\alpha}\sin 2\theta_0.
\end{array}\right\} \quad (30)$$

Case (β):

$$\left.\begin{array}{l}
\text{Total optical path of atmospheric ray} \\
\quad = \displaystyle\int \mu\, ds = \frac{2h}{\cos\theta_0} + \frac{\pi}{2\sqrt{\beta}}(1 + \sin^2\theta_0) \\
\text{Total equivalent path of atmospheric ray} \\
\quad = \displaystyle\int \frac{ds}{\mu} = \frac{2h}{\cos\theta_0} + \frac{\pi}{\sqrt{\beta}} \\
\text{Path of ground ray} \\
\quad = d = 2h\tan\theta_0 + \displaystyle\frac{\pi\sin\theta_0}{\sqrt{\beta}}.
\end{array}\right\} \quad (31)$$

Now the recognition of the essential equivalence of the wave-length change method and the group-retardation method was based on the proof that, for such cases as we are considering $\int \mu ds - \lambda \frac{\delta}{\delta\lambda} \int \mu ds$ was equal to the equivalent path $\int \frac{ds}{\mu}$. In attempting to demonstrate this for these particular cases we note that, in finding the value of the expression $\frac{\delta}{\delta\lambda} \int \mu ds$, we require to know both $\frac{\partial\alpha}{\delta\lambda}\left(\text{or } \frac{\partial\beta}{\partial\lambda}\right)$ and $\frac{\partial\theta_0}{\partial\lambda}$, for the expression for $\int \mu ds$ involves both these quantities. Now in an ionized medium in which the frequency of the electronic collisions with the gas molecules is small, we may write

$$\mu^2 = 1 - A\lambda^2, \tag{32}$$

where A is a quantity (*) which is proportional to the ionization. Thus for our two cases we have

$$\text{Case } (\alpha) \qquad \mu^2 = 1 - \alpha y = 1 - B\lambda^2 y,$$

$$\text{Case } (\beta) \qquad \mu^2 = 1 - \beta y^2 = 1 - C\lambda^2 y^2,$$

where B and C are constants. From these expression $\frac{\partial\alpha}{\partial\lambda}$ and $\frac{\partial\beta}{\partial\lambda}$ may be calculated. Also, from the expressions for the total path of the ground ray in each case we can find $\frac{\partial\theta_0}{\partial\lambda}$ after making the substitution for $\frac{\partial\alpha}{\partial\lambda}$ or $\frac{\partial\beta}{\partial\lambda}$ as the case may be. In this way we arrive at the value of $\int \mu ds - \lambda \frac{\delta}{\delta\lambda} \int \mu ds$ for the total atmospheric paths in the two cases. These are found to be

$$\text{Case } (\alpha) \quad \int \mu\, ds - \lambda \frac{\delta}{\delta\lambda} \int \mu\, ds = \frac{2h}{\cos\theta_0} + \frac{4}{\alpha}\cos\theta_0, \tag{33}$$

$$\text{Case } (\beta) \quad \int \mu\, ds - \lambda \frac{\delta}{\delta\lambda} \int \mu\, ds = \frac{2h}{\cos\theta_0} + \frac{\pi}{\sqrt{\beta}}. \tag{34}$$

But from (30) and (31) we see that these expressions are exactly those for the equivalent paths. We therefore have verified the statement that in the wave-length change method we measure the equivalent path $\int \frac{ds}{\mu}$ and not the optical path $\int \mu ds$.

From the point of view of deducing information concerning a and b from experimental determinations of $c\Delta t$ or $\lambda^2 \frac{\delta n}{\delta\lambda}$ we note that the relevant equations are as follows :

$$\text{Case } (\alpha) \quad c\Delta t = \lambda^2 \frac{\delta n}{\delta\lambda} = \frac{2h}{\cos\theta_0} + \frac{4}{\alpha}\cos\theta_0 - d. \tag{35}$$

$$\text{Case } (\beta) \quad c\Delta t = \lambda^2 \frac{\delta n}{\delta\lambda} = \frac{2h}{\cos\theta_0} + \frac{\pi}{\sqrt{\beta}} - d. \tag{36}$$

4. Methods of investigating the ionization gradient.

We have seen that for short waves any one of the three methods discussed above will enable us to find the value of $\int \frac{ds}{\mu}$ for the atmospheric ray. This quantity is equal to the length AFE in figure 3, from which, knowing d, we may find sin θ_0 which is equal to the refractive index at the point C. Now since, for short waves, we have

$$\mu^2 = 1 - \frac{4\pi Ne^2}{mp^2}, \tag{37}$$

a knowledge of the refractive index enables us to calculate the electron concentration N at the point C. If we could measure the actual height of point C in some other way we should be able to specify the ionization at a particular height.

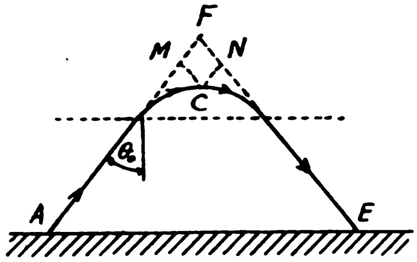

Fig. 3.

Let CM and CN (in fig. 3) be perpendiculars from O on to AF and FE respectively. Now Pedersen has shown (*) that the optical path $\int \mu ds$ of the atmospheric ray, when $\theta_0 > 30°$, is approximately (actually slightly smaller than) AM + NE. If, therefore, it were possible to determine both $\int \frac{ds}{\mu}$ and $\int \mu ds$ for the atmospheric ray we should be able to find both the ionization at and height of point C. The equivalent path would fix for us the position of F and enable us to calculate the ionization at C, while the optical

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(*) A is actually equal to $\frac{Ne^2}{\pi mc^2}$ where N is the number of electrons, of charge e and mass m, per c. c.

(*) *The Propagation of Radio Waves*, Copenhagen, 1927, p. 176.

path would fix the positions of M and N from which the position of C could be found. To a method of estimating the optical path of the atmospheric ray we now turn.

It will be found convenient to re-write (1) in terms of the frequency f instead of the wave-length λ. Thus

$$n = \frac{fD}{c}$$

and

$$\frac{dn}{df} = \frac{D}{c} + \frac{f}{c}\frac{dD}{df}. \tag{38}$$

Now it is possible to carry out experiments in which $\frac{dn}{df}$ is measured for a large number of frequencies at about the same time and under the same conditions of transmission distance, etc. This quantity would, in general, be a function of the frequency and may be written $\Phi(f)$. Thus (30) becomes

$$\frac{dD}{df} + \frac{D}{f} = \frac{c}{f}\Phi(f), \tag{39}$$

the solution of which is given by

$$Df = c\int \Phi(f)\,df + \text{const.} \tag{40}$$

We thus see that, even if $\Phi(f)$ is known for a considerable range of frequencies, we cannot find D exactly for any particular frequency since the constant is unknown. If, however, after having obtained values of $\Phi(f)$ for as low frequencies as we can in practice, we draw the curve showing the relation between $\Phi(f)$ and f and extrapolate it to the limit of zero frequency we can get over this difficulty and write

$$D_0 f_0 = c\int_0^{f_0} \Phi(f)\,df, \tag{41}$$

where D_0 is the optical path difference for a particular frequency f_0. The optical path of the atmospheric ray for the very high frequencies could then be found and the ionization at certain particular heights determined by the method outlined above.

It should be noted that the measurements of $\frac{dn}{df}$ would have to be made at a considerable distance from the transmitter to fulfil the conditions under which the relation of Pedersen holds, and it is most probable that, as the frequency is increased to the values for which the influence of the earth's magnetic field is negligible, the strength of the ground waves at the receiving station would be too small to detect. In such cases the suggestion made above of using at the same time a long wave-length to send out the modulation (*e.g.* pulses of Breit and Tuve) might be useful.

The method described above deals with measurements made at one receiving station with different mean frequencies. It is, however, possible that information of similar character might be obtained by making simultaneous observations on the same mean frequency at different distances as the following considerations show.

We have seen that any one of the three direct methods considered will enable us to find the equivalent height OF (*i. e.* $h + h'$ in fig. 1). Considering again the cases of special types of ionization gradients we find from (35)

$$\lambda^2\frac{\delta n}{\delta\lambda} + d = \frac{2(h+h')}{\cos\theta} = \frac{2h}{\cos\theta_0} + \frac{4\cos\theta_0}{\alpha},$$

or

$$h + h' = h + \frac{2}{\alpha}\cos^2\theta_0, \tag{42}$$

and similarly from (36)

$$h + h' = h + \frac{\pi\cos\theta_0}{2\sqrt{\beta}}. \tag{43}$$

We thus see that, for a case of ionization varying directly with the height, the equivalent height should vary linearly with $\cos^2\theta_0$ for observations made at various distances, where as for ionization varying as the square of the height the equivalent height should vary linearly with $\cos\theta_0$. Corresponding equations for other types of gradient could be found (*) and by comparing the equivalent heights at different distance we should be able to ascertain which type of gradient gives the closest approximation. When this decision has been made the observations

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(*) For example with $\mu^2 = 1 - ke^{\gamma y}$, where $k \lll 1$, I find that the equivalent height is approximately equal to $h + \frac{1}{\gamma}$, a quantity independent of the distance. Thus such a gradient would simultate a sharp boundary.

from any two stations would enable us to find both h and α (or β) from which the ionization at definite heights could be stated. Additional evidence could be obtained by making the experiments with different wave-lengths since α (or β) depends on the wave-length. For example, once the type of gradient had been determined, it would also be possible to find h and α (or β) from observations made at any one station on two different wave-lengths. The results could therefore be checked.

The problems discussed in this paper arose in connection with investigations the authors is carrying out for Radio Research Board of the Department of Scientific and Industrial Research.

APPENDIX I

To find the variation in the optical path of the atmospheric ray.

Consider figure 1 in which the track of the atmospheric ray ABCHE begins at the origin A and finishes at E (x_0, o). We have

$$\int \mu\, ds = \int_0^{x_0} \mu \frac{ds}{dx}\, dx. \tag{1'}$$

Now if the refractive index is (as in the most general case of the magneto-ionic theory) a function of both position, ray-direction and wave-length we write.

$$\mu = f(x, y, z, \lambda, y', z'). \tag{2'}$$

Thus

$$\left.\begin{aligned} \delta \int \mu\, ds &= \delta \int_0^{x_0} \mu \frac{ds}{dx}\, dx \\ &= \int_0^{x_0} \delta\mu \frac{ds}{dx}\, dx + \mu\delta\left(\frac{ds}{dx}\right) dx \\ &= \int_0^{x_0} \left(\frac{\partial\mu}{\partial y}\delta y + \frac{\partial\mu}{\partial z}\delta z - \frac{d}{dx}\left(\frac{\partial\mu}{\partial y'}\right)\delta y \right. \\ &\qquad \left. - \frac{d}{dx}\left(\frac{\partial\mu}{\partial z'}\right)\delta z + \frac{\partial\mu}{\partial\lambda}\delta\lambda\right)\frac{ds}{dx}\, dx \\ &\qquad + \int_0^{x_0} \mu\delta\left(\frac{ds}{dx}\right) dx. \end{aligned}\right\} \tag{3'}$$

But by the principle of least time, as interpreted by Hamilton, the terms on the righ-hand side representing path variations vanish leaving only the term involving the wave-length variation. Thus

$$\left.\begin{aligned} \delta \int \mu\, ds &= \int_0^{x_0} \frac{\partial\mu}{\partial\lambda}\delta\lambda \frac{ds}{dx}\, dx \\ &= \int \frac{\partial\mu}{\partial\lambda}\, ds\, \delta\lambda. \end{aligned}\right\} \tag{4'}$$

APPENDIX II

The relation between phase and group velocities.

The relation between group velocity U and phase velocity V is given by

$$\frac{1}{\mathrm{U}} = \frac{\partial}{\partial f}\left(\frac{f}{\mathrm{V}}\right), \tag{1''}$$

where f is the frequency of the waves. But V is equal to $\frac{c}{\mu}$ so that this becomes

$$\left.\begin{aligned} \frac{1}{\mathrm{U}} &= \frac{1}{c}\frac{\partial}{\partial f}(f\mu) \\ &= \frac{1}{c}\left(\mu + f\frac{\partial\mu}{\partial f}\right) \\ &= \frac{1}{c}\left(\mu - \lambda\frac{\partial\mu}{\partial\lambda}\right). \end{aligned}\right\} \tag{2''}$$

Thus for any particular path we have

$$c\int \frac{ds}{\mathrm{U}} = \int \mu\, ds - \lambda \int \frac{\partial\mu}{\partial\lambda}\, ds. \tag{3''}$$

This equation is to be compared with

$$\lambda^2 \frac{\delta n}{\delta\lambda} + \mathrm{AE} = \int \mu\, ds - \lambda \frac{\delta}{\delta\lambda}\int \mu\, ds, \tag{4''}$$

which may be derived from (2) and (3).

In conclusion I wish to express my particular indebtedness to my collaborator Mr. J. A. Ratcliffe, who first raised the question of the essential equivalence of the quantities measured in the wave-length change method and in the method of Breit and Tuve by pointing out to me the close similarity between equations (3″) and (4″), which are the representative relations for the two methods. To Mr. S. Goldstein I am also greatly indebted for advice on certain mathematical points.

LES PHENOMENES DE PROPAGATION DES ONDES RADIOTELEGRAPHIQUES.

Note de M. R. JOUAUST, présentée par M. le Général FERRIÉ.

On ne saurait douter aujourd'hui que les grandes portées réalisées par les ondes radiotélégraphiques, en particulier par celles inférieures à 100 mètres, sont dues à des propriétés particulières de la haute atmosphère, mais le mécanisme de la propagation de ces ondes est encore mal connu. On admet l'existence dans la partie supérieure de la stratosphère d'une couche fortement inonisée qui renverrait vers le sol les ondes rayonnées dans l'espace par une réflexion ou plus exactement par une réfraction, c'est-à-dire par un phénomène du même genre que le mirage.

Mais cette explication ne rend pas compte de divers faits observés. Les ondes réfractées ne pourraient revenir au sol qu'à une distance assez éloignée du transmetteur et l'on a pu constater en produisant des signaux brefs, l'existence d'échos, existence qui se manifeste déjà à quelques kilomètres du poste émetteur. Ces échos parfois multiples semblent provenir d'une altitude de 200 à 400 kilomètres, altitude qui varie souvent en quelques instants. Enfin, la théorie de la réfraction nécessite une certaine homogénéité de la haute atmosphère et les divers auteurs qui ont cherché à la traitèr mathématiquement ont dû admettre pour la densité ionique (nombre d'électrons par unité de volume) une loi de variation régulière en fonction de l'altitude.

Cette dernière hypothèse paraît peu vraisemblable. Les relations entre l'activité solaire et l'état magnétique terrestre semblent bien indiquer, comme l'ont montré tout récemment encore les travaux de Maurain, que les variations des constantes magnétiques sont dues à une ionisation à grande altitude provoquée par des particules émanées du soleil, les mêmes dont l'arrivée dans notre atmosphère se manifeste souvent par des aurores.

Le fait que les échos semblent provenir d'une hauteur qui correspond à celle des aurores, que d'autre part la raie verte caractéristique des aurores, est visible sous toutes les latitudes, conduit à supposer que ce sont ces mêmes causes d'ionisation qui interviennent dans la propagation des ondes.

Cette émission de particules électrisées par le soleil présente évidemment le même caractère de discontinuité que l'émission d'électrons par les corps incandescents (effet Schottky).

Il est donc probable que la densité ionique de la haute atmosphère présente d'importantes fluctuations et qu'on doit considérer que les couches élevées de la stratosphère contiennent des nuages d'électrons dont les dimensions sont du même ordre que celles des ondes radiotélégraphiques.

Ces nuages électroniques seraient donc capables de diffuser les ondes dans toutes les directions.

Sans prétendre qu'il faille chercher à expliquer par la diffusion tous les faits observés en radiotélégraphie, nous voulions attirer l'attention sur un phénomène qui est susceptible de jouer un rôle important et qui, à notre connaissance, a été complètement négligé par tous les physiciens qui se sont occupés de la question.

NOTE SUR LES RESEAUX ELECTROMAGNETIQUES EN GRECQUE OU EN DENTS DE SCIE

par René MESNY.

Nous avons montré comment on pouvait établir un réseau électromagnétique d'émission au moyen d'un fil replié en grecque et alimenté en son milieu (*): il suffit de donner aux différents éléments du fil une disposition telle que la longueur comptée entre les milieux A et B de deux brins horizontaux consécutifs (fig. 1), soit égale à la moitié de la longueur de l'onde qui se propage sur ce fil. Les courants stationnaires dans tous les brins verticaux sont alors en phase et donnent naissance à un faisceau dont l'axe est normal au plan du réseau.

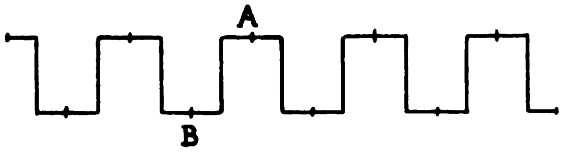

FIG. 1.

L'expression du champ dans une direction quelconque s'établit immédiatement quand on néglige l'amortissement le long du fil; mais, pour comparer les résultats de l'expérience avec les prévisions théoriques il est bon de tenir compte de la diminution du courant du milieu vers les extrémités. La détermination rigoureuse de ce courant, impossible pour un fil rectiligne, l'est *a fortiori* dans le cas du fil replié; mais on sait que l'expression que l'on obtient pour le fil rectiligne en supposant l'inductance, la capacité et la résistance également réparties, donne des résultats voisins de ceux de l'expérience. En appliquant la même méthode au cas actuel, on peut donc espérer que l'on obtiendra une solution suffisamment approchée qui permettra de calculer un diagramme de directivité assez précis.

Atténuation du courant dans les brins successifs. — En appelant λ la longueur de l'onde sur le fil, ρ et l la résistance et l'inductance unitaires de ce dernier, ω la pulsation, $2m\lambda$ la hauteur des brins verticaux, et en posant :

$$\alpha = \frac{2\pi}{\lambda}, \quad \operatorname{tg} \varphi = \frac{\rho}{l\omega}, \quad \tau = \operatorname{tg} \frac{\varphi}{2}$$

l'amplitude du courant moyen le long du brin de rang p — ce rang étant compté à partir de l'extrémité du réseau — est donnée par la formule :

$$|\mathrm{I}_p| \sim \frac{\operatorname{ch}^2(2\pi m\tau) - \cos^2(2\pi m)}{m} \operatorname{ch}\left[(2p-1)\tau\frac{\pi}{2}\right]. \qquad (1)$$

La phase de ce courant est, bien entendu, indépendante de p. Cette relation permet de calculer facilement l'atténuation du courant entre le milieu et l'extrémité du réseau. Si la longueur de ce dernier est $2\,l$ et l'écartement de deux brins consécutifs verticaux d, on a sensiblement :

$$\frac{\text{intensité dans le premier brin}}{\text{intensité dans le brin milieu}} = \frac{1}{\operatorname{ch}\left[\left(\frac{2l}{d}+1\right)\tau\frac{\pi}{2}\right]}$$

On peut remarquer que pour des antennes semblables, qui correspondent à des ondes dans le même rapport de similitude, la valeur de τ est constante. Le rapport $\frac{\rho}{l\omega}$ est en effet égal à $\frac{\mathrm{R}}{\mathrm{L}\omega}$, R et L étant la résistance et la self-inductance d'une longueur de fil égale à une demi-onde; or, $\mathrm{L}\omega$ est évidemment constant dans les conditions actuelle et il est facile de voir qu'il en est de même pour R; pour $d = \frac{\lambda}{4}$, on trouve pour τ une valeur voisine de 0,035 que l'expérience confirme.

(*) Mesny. Emissions dirigées par rideaux d'antennes. (*Onde Électrique*, **6**, mai 1927, pp. 181-200.)

Dans les mêmes conditions, le rapport précédent a une valeur de 0,7 pour $2\,l = 4\lambda$ et 0,17 pour $2\,l = 10\lambda$. (*).

Champ du réseau. — Enfin, en assimilant le réseau discontinu que l'on vient d'étudier à un réseau « continu », constitué par une nappe de courant dans laquelle le courant varierait suivant une loi correspondante à celle donnée par la formule 1, on peut calculer une expression du champ rayonné; nous avons montré (*loc. cit.*) que le champ d'un tel réseau s'écarte peu de celui d'un réseau discontinu dans lequel les brins verticaux sont à une distance inférieure à un quart d'onde. En appelant n le nombre d'antennes du réseau discontinu et en définissant la direction du point où le champ est E, par l'angle θ que fait cette direction avec la verticale et par l'angle δ qu'elle fait avec la ligne ox suivant laquelle est aligné le réseau (fig. 2); en posant enfin :

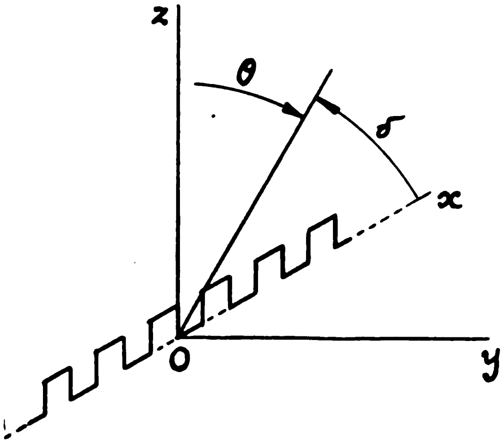

FIG. 2.

$$\frac{\pi n \tau}{2} = a, \quad \frac{\pi (n-1) \tau}{2} = b, \quad \frac{2\pi l}{\lambda} \cos \delta = \gamma$$

on trouve pour la composante verticale du champ électrique :

$$\mathrm{E} \sim \frac{1}{b^2 + \gamma^2} \begin{bmatrix} b \,\mathrm{sh}\, a + \gamma \sin \gamma \,\mathrm{ch}\, (a - b) \\ - b \cos \gamma \,\mathrm{sh}\, (a - b) \end{bmatrix} \sin \theta. \quad (2)$$

Influence d'un désaccord. — Si l'on suppose que la longueur AB de la figure 1 soit différente d'une demi-onde, les courants dans les brins successifs sont décalés et le décalage va en augmentant depuis les extrémités du réseau jusqu'au milieu; il en résulte une modification du courant moyen I_p dans le brin de rang p. En désignant par $(1 + \varepsilon) \frac{\lambda}{2}$ la longueur AB on trouve :

$$|\mathrm{I}_p| \sim \cos \left[(2p - 1)\, \varepsilon \frac{\pi}{2} \right] \mathrm{ch} \left[(2p - 1)\, \tau \frac{\pi}{2} \right]. \quad (3)$$

Quant à la phase de ce courant elle est donnée sensiblement par :

$$\mathrm{tg}\, \varphi_p = - \frac{1}{\tau} \frac{1 - \frac{\pi}{2} \tau^2 \,\mathrm{tg} \left[(2p - 1)\, \varepsilon \frac{\pi}{2} \right]}{1 + \frac{\pi}{2} \tau \,\mathrm{tg} \left[(2p - 1)\, \varepsilon \frac{\pi}{2} \right]}. \quad (4)$$

Nous avons laissé de côté la diminution d'intensité qui résulte du désaccord, car elle affecte proportionnellement tous les courants.

Il résulte de là qu'un petit désaccord n'est pas nuisible à la directivité; en effet, dans la formule 3, la décroissance du cosinus circulaire qui résulte de l'augmentation de p compense en partie la croissance du cosinus hyperbolique. En outre, τ étant une quantité très faible, la formule 4 montre que la phase varie très peu d'un bout à l'autre du réseau si celui-ci reste dans les conditions de la pratique. Pour $\varepsilon = 0{,}03$ et $p = 9$, φ_p passe de 2° à 5° quand on va du brin extrême au brin de rang 9.

Réseaux à rayonnement longitudinal. — Dans la pratique on n'a encore utilisé que des réseaux dont les antennes sont parcourues par des courants en phase. De tels réseaux donnent lieu à un système de deux faisceaux transversaux, symétriques par rapport au plan du réseau et dont l'axe commun est normal à ce plan; pour obtenir un rayonnement unidirectionnel, il faudrait ajouter au précédent un réseau réflecteur.

Avec un réseau dans lequel il existerait entre les courants de deux antennes consécutives une différence de phase correspondant à la différence de marche de l'onde entre elles, on pourrait obtenir directement un faisceau unidirectionnel. Le faisceau serait longitudinal, c'est-à-dire que sa direction privilégiée serait dans le plan du réseau. Un tel faisceau serait notablement moins

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(*) Toutes ces considérations s'appliquent facilement aux réseaux en dents de scie de Chireix. (Société Française Radio-Électrique. Perfectionnement aux antennes. Brevet français 216.757, 10 mars 1926.)

étendu que le précédent dans le sens de la hauteur, mais à égalité de la longueur du réseau, il serait beaucoup plus large.

Ces réseaux seraient plus difficiles à construire à cause des différences de phases à réaliser, mais M. Latour a fait remarquer que l'on pourrait les obtenir facilement avec des antennes en grecques ou en dents de scie en utilisant soit des ondes stationnaires, comme ci-dessus, soit des ondes progressives; il suffirait d'établir un rapport convenable entre les dimensions horizontale et verticale d'un élément.

Comme on pourrait songer à l'emploi d'un semblable système pour concentrer l'énergie rayonnée dans la direction horizontale, il est intéressant de comparer dans les deux cas les champs obtenus dans l'axe du faisceau, à égalité de puissance dépensée.

En supposant la hauteur *h* des brins verticaux du réseau très petite par rapport à la longueur d'onde, on peut calculer la puissance rayonnée par un réseau simple de *n* antennes à rayonnement transversal. Avec les mêmes notations que ci-dessus, on trouve en unités pratiques (*) :

$$W_T = 30\pi^2 n^2 \frac{h^2}{2l\lambda} I_{eff}^2.$$

D'autre part, si W_L désigne la puissance rayonnée par un réseau à rayonnement longitudinal, ayant la même longueur et le même nombre d'antennes de même hauteur, parcourues par le même courant, on trouve au deuxième ordre près :

$$\frac{W_L - W_T}{W_T} = \frac{-2}{\pi\alpha l}\int_0^{2\alpha l} \frac{\sin^2 u}{u}\, du$$

et cette quantité est inférieure à 0,08 quand la longueur 2 *l* est $\geqslant 5\lambda$. Les deux réseaux dépensent donc à peu près la même puissance pour produire le même champ dans la direction privilégiée, puisque celui-ci ne dépend que du nombre des antennes, de leur forme et du courant qui les parcourt. Mais le premier rayonne deux faisceaux symétriques; si l'on y ajoute un réflecteur et que l'on maintienne la même intensité dans les antennes, on double le champ dans la direction privilégiée et le calcul montre que la puissance à fournir est seulement doublée.

On en déduit facilement qu'à champs égaux dans la direction privilégiée, un réseau unidirectionnel à rayonnement transversal demande deux fois moins de puissance environ qu'un réseau à rayonnement longitudinal. Cette conclusion doit être prise en considération dans la recherche d'un système concentrant le plus possible le rayonnement dans le voisinage de l'horizon; il n'est d'ailleurs pas établi qu'une telle concentration soit avantageuse pour l'établissement de communications sur ondes courtes.

(*) MESNY. Rayonnement des réseaux. — C. R., T. 184, 1897, 1047.

A NEW TRANSFORMATION IN ALTERNATING CURRENT THEORY WITH AN APPLICATION TO THE THEORY OF AUDITION

by BALTH. VAN DER POL, D. Sc.

In ordinary linear alternating current theory an inductive reactance is usually represented by $+j\omega L$ while a capacitive reactance is denoted by $-\frac{j}{\omega C}$. Therefore the *imaginary* part of an impedance may have a positive as well as a negative sign. As long as positive resistances only were known the *real* part of an impedance was always positive (independant upon the constitution of the network considered). But with the advent of negative resistances (such *e. g.* as the arc, the dynatron or the triode with retroaction) the real part of an impedance, like the imaginary part, may have both signs.

The transformations to be considered here (and which may be called *j-transformations*) consist of multiplying all complex impedances of a network by j, j^2, j^3 and j^4 respectively where $j = \sqrt{-1}$. Through *mathematically* these trans-

formations obviously only represent a turning of the impedance vectors by angles $\frac{\pi}{2}$, π, $\frac{3\pi}{2}$ and 2π respectively the *physical* interpretation of these transformations may lead to some new circuits or to at first sight unexpected relations between circuits with well-known properties.

Obviously the j^4-transformation transforms the circuit into itself and therefore does not yield anything new. On the other hand the j^2-transformation implies the multiplication of any circuit element with — 1. This means that in the network considered every positive resistance is to be replaced by a negative resistance of the same absolute amount, and vice versa. Moreover every positive inductance must be replaced by a negative inductance and vice versa, and also every positive capacity by a negative capacity and vice versa. With this physical interpretation of the j^2 transformation any network thus transformed retains its impedances (but multiplied by —1) *for all frequencies*. The necessity of constructing *negative inductances* and *negative capacities* does not (at least on paper) yield any difficulties, now that negative resistances are at hand; for the equivalent network of figure 1*a* is figure 1*b* as can be easily verified.

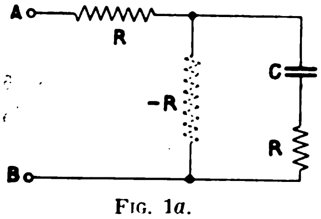

FIG. 1*a*.

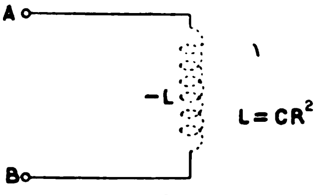

FIG. 1*b*.

We can therefore with the aid of two positive and one negative resistance and a capacity construct a negative inductance which is independent of frequency. The circuit of figure 1*a* thus behaves exactly as if between the terminals A—B a negative inductance were inserted of amount $L = CR^2$.

Similarly, a negative capacity (again independent of frequency) may be obtained as in figure 2 which speaks for itself (*). Thus the network of figure 2*a* is equivalent to a negative capacity of amount $C = LR^{-2}$ (fig. 2*b*), as is easily verified.

Of course unstabilities often arise in circuit comprising, inter's alias, negative resistances. The stability of such a circuit can, however, be calculated. We therefore imagine with Barkhausen (*Phys. Zschr.*, 27, 43, 1926) a small inductance to be inserted in series with an arc, and a small capacity to be shunted to a dynatron or triode. This system can then further be investigated with the aid of the *Hurwitz* determinants, giving the conditions that the real part of all the roots of an equation are negative. (I found that these determinants can be considerably simplified and hope to report on this subject shortly.)

Coming now to the *j-transformation* and the j^3*-transformation* it will be clear that the latter can be derived from the former by a j^2*-transformation* so that we can further limit ourselves to consider the j-transformation only.

As the reactance of a self inductance and of a capacity depends upon the angular frequency ω of the impressed E.M.F. the j-transformation can be used for one given frequency at the time only, so that when a different frequency is considered the physical, numerical result of the j-transformation is also different. In applying the j-transformation, every positive resistance R in the network, through the multiplication by j, becomes jR, and this has to be interpreted physically as $j\omega L'$, *i. e.* every positive resistance R is transformed into an inductance L', of amount $L' = R\omega^{-1}$. Similarly every negative resistance —R has to be replaced by a capacity C' such that $C' = (\omega R)^{-1}$. Further, every impedance $j\omega L$ becomes $jj\omega L = -\omega L = -R'$, i. e. every inductance L has to be replaced by a negative resistance — R' of an amount $R' = (\omega L)^{-1}$ Finally, every capacitive reactance $\frac{1}{j\omega C}$ becomes $\frac{j}{j\omega C} = (\omega C)^{-1}$. This expression is real and positive,

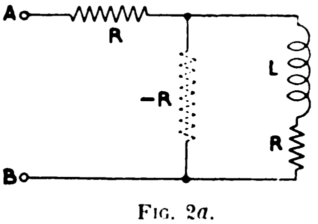

FIG. 2*a*.

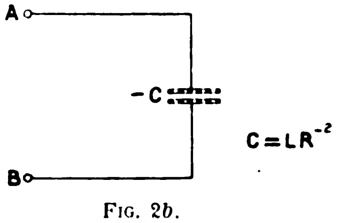

FIG. 2*b*.

(*) See BARTLETT, *Journ. Inst. of Electr Eng.*, London, 65, 373, 1927; also: British Patent 278.036.

hence every capacity (of value C) has to be replaced by a resistance R′, where $R' = (\omega C)^{-1}$.

It will be clear that in ordinary vectorial representation the j-transformation simply means revolving a vector diagram as a whole over 90°, and then to inquire into the physical meaning of the revolved diagram.

The j-transformation could obviously be extended to transformations such as a $j^{\frac{1}{2}}$ -transformation, meaning a rotation over an angle $\frac{\pi}{4}$. However, we will limit ourselves here to integral powers of j only.

Consider *e. g.* a series connection of L, C, $+r$, and $-r_2$. Upon this linear system an E.M.F. be impressed of angular frequency ω. By varying the L or the C we may bring the system into « reactance-resonance ». When, as in a wireless receiver with retroaction, we thereupon make r_2 as near as possible equal to r_1 (*i. e.* adjust the retroaction to the critical point), we do the same thing over gain, but only after one j-transformation, and one could say in a broad sense, that adjusting the total resistance near zero value means bringing the system into « resistance-resonance ».

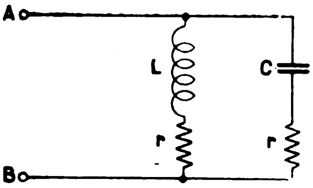

FIG. 3*a*.

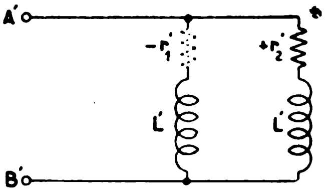

FIG. 3*b*.

We will now consider some simple a. c. circuits having special properties and inquire as to what becomes of them after a j-transformation.

Example 1.

Consider figure 3*a*, representing a well-known circuit, such as often used, e. g., in a triode amplifier. This circuit has the property that for resonance, i. e. for

$$j\omega L = -\frac{1}{j\omega C} \tag{1}$$

the equivalent impedance Z_{AB} between the points A-B is

$$Z_{AB.} = \frac{\frac{L}{C} + r^2}{2r} \tag{2}$$

and is therefore real, i. e. a pure resistance. After one j-transformation, figure 3*a* is changed into figure 3*b*, such that

$$\begin{aligned} j\omega L &= -r_1', \\ \frac{1}{j\omega C} &= +r_2', \\ r &= j\omega L', \\ r &= j\omega L'. \end{aligned}$$

Thus the condition (1) becomes

$$r_1' = r_2' \tag{1′}$$

i. e. in the derived circuit the equality of the moduli of the two resistances corresponds to the resonance condition of the original circuit. And, further, the special property (2) of the original circuit becomes, after our j-transformation :

$$Z'_{A'B'} = \frac{-r_1'r_2' - \omega^2 L'^2}{2j\omega L'} = j\omega L' \cdot \frac{\omega^2 L'^2 + r'^2}{2\omega^2 L'^2} \tag{2′}$$

or, in other words, the system of figure 3*b* behaves as a pure inductance when the numerical values of $-r'_1$ and r'_2 are made equal.

Example 2.

The circuit of figure 4*a* has the property that when

$$j\omega L = -\frac{1}{j\omega C}$$

i. e. in resonance, the current i_z through the arbitrary impedance Z is independent of this impedance, *viz.*

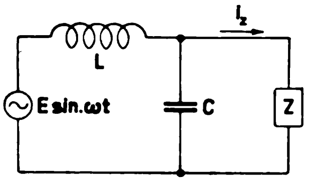

FIG. 4*a*.

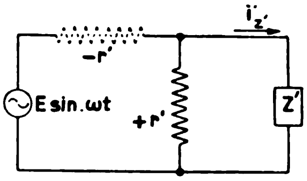

FIG. 4*b*.

$$i_Z = \frac{E}{j\omega L}. \tag{3}$$

After the application of the j-transformation, figure 4*a* becomes figure 4*b*. Here, again, the resonance condition of figure 4*a* is changed into the equality of the numerical values of the two resistance $-r'$ and r' in figure 4*b*. The arbitrary impedance Z of figure 4*a* is transformed into another arbitrary impedance Z′ of figure 4*b*. Again (3) changes into

$$i_{z'} = -\frac{E}{r'}, \tag{3'}$$

or in words : the current through Z′ is independent of the impedance Z′ itself so that, when instead of E sin ωt, an E.M.F. is applied of arbitrary wave-form, the current through Z′ is an exact image in amplitudes as well as in phases of the applied E.M.F. (*).

Example 3.

Let a given current *i* be flowing between the terminals A and B of figure 5*a*. It is easy to

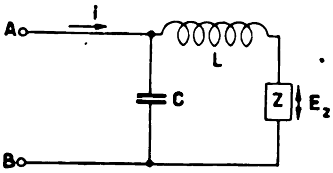

FIG. 5*a*.

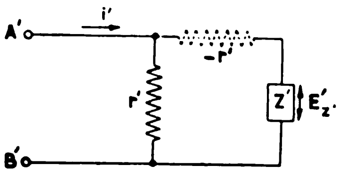

FIG. 5*b*.

show that for resonance the P. D. E_Z developing accross the impedance Z will be

$$E_Z = \frac{i}{j\omega C}$$

and therefore does *not* depend upon the value or constitution of Z.

The *j*-transformation of figure 5*a* is given by figure 5*b*. If in the latter the negative resistance $-r'$ is numerically made equal to the positive resistance r', then the P. D. developping across the arbitrary impedance Z′ is an exact image of the current *i′* entering the system, independent of its waveform.

Example 4. (Application to the theory of audition.)

Consider the circuit of figure 6*a*. For an impressed E. M. F. of a frequency ω given by

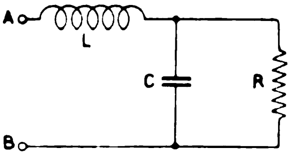

FIG. 6*a*.

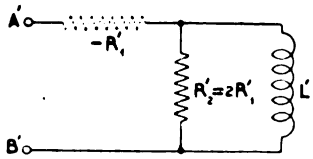

FIG. 6*b*.

$$\omega^2 = \frac{1}{2LC} \tag{4}$$

the impedance Z_{AB} between the terminals AB is given by

$$Z_{AB} = j\omega L \cdot \frac{1 - j\omega CR}{1 + j\omega CR} = j\omega L \, . \, e^{-2j\theta}$$

where

$$\text{tang}\,\theta = \omega CR.$$

We therefore see that for the specific frequency given by (4) the modulus of the impedance between the points A and B of figure 6*a* does not vary with the value of R. If, thus, an alternating E.M.F. of constant amplitude and of frequency $\omega^2 = (2LC)^{-1}$ is maintained between the terminals A-B, the amplitude of the current through the L branch is unaffected by the value of R, but its phase is. This is a very valuable property for measurement purposes, as we can change the phase over 180° without affecting the amplitude.

When we now apply again the *j*-transformation to the system of figure 6*a*, figure 6*b* is obtained.

The frequency condition (4) of the former circuit, which can be written

$$j\omega L = \frac{-1}{2j\omega C}$$

now becomes

$$R'_2 = 2R'_1$$

and does *not* depend upon the frequency. The impedance $Z'_{A'B'}$ of figure 6*b* now becomes

$$Z'_{A'B'} = -R'_1 \cdot \frac{R'_2 - j\omega L'}{R'_2 + j\omega L'} = -R'_1 e^{-2j\theta'} \tag{5'}$$

where

$$\text{tang}\,\theta' = \frac{\omega L'}{R'_2}. \tag{6'}$$

Our circuit of figure 6*b* has therefore the following properties : *the modulus of the impedance of the network between the points A′ and B′ is the same for all frequencies and does not depend upon the value of L′. The phase, however, does depend upon the value of L′. If we therefore apply an E.M.F. of any complicated wave-*

(*) This porperty of figure 4*b* was already derived by Bartlett, *l. c.*

form to the terminals A′B′ all the amplitudes of the various harmonic components of the current entering at A′ will be exactly proportional to the corresponding amplitudes of the harmonics of the E.M.F. The phases of the currents, however, are shifted relatively to the phases of the E.M.F., and to an amount depending upon the frequency.

The limiting cases can be recognized directly. For a very low frequency the L′ branch forms a short circuit in parallel to the R'_2 branch. Hence, for a very low frequency the impedance $Z'_{A'B'}$ approaches $-R'_1$. For a very high frequency on the other hand the branch L′ (in parallel to the R'_2 branch) can be ignored, thus leaving a total impedance $Z'_{A'B'} = -R'_1 + R'_2 = -R'_1 + 2R'_1 = + R'_1$. Thus the total possible phase-change is 180°.

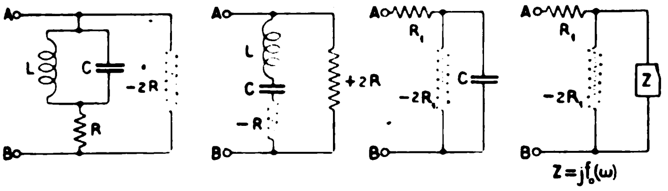

Fig. 7.

Several circuits possessing the above properties can be designed. Some other instances are given in figure 7. (By $Z = jf_0(\omega)$ is meant any impedance consisting of inductances and capacities only.)

For all those circuits having the above property the impedance Z can be expressed as

$$Z = R \cdot \frac{f_e(\omega) - jf_0(\omega)}{f_e(\omega) + jf_0(\omega)} = R \cdot e^{-2j\theta}$$

where

$$\operatorname{tang} \theta = \frac{f_0(\omega)}{f_e(\omega)}$$

and where $f_e(\omega)$ and $f_0(\omega)$ represent and even and an odd function of ω respectively, and where R represents an ohmic resistance.

It may be remarked that the circuits considered are quite different from the circuit of figure 8, described by *Möller* (*) where the amplitude of the *potential* between A-B is independent of the frequency of the source E sin ω *t*, while the phase is dependent upon it. However, this is only true as long as the internal resistance of the source E sin ω*t* is zero, which is difficult to realise in practice with triodes.

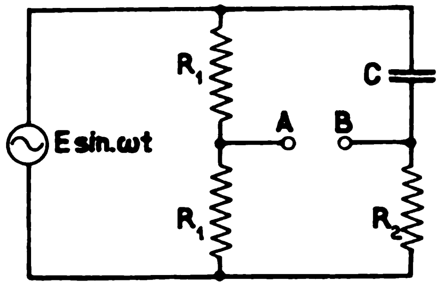

Fig. 8.

The property described of leaving the amplitudes of all the composing harmonics untouched but only changing their phases gives us a means of verifying experimentally the well known acoustical law of *Ohm*, stating that our ear perceives from a complicated sound the amplitudes of the various components only, but that it can not recognize the phases of those components. Therefore arbitrary changes made in the phases of the components does not vary our perception of a sound as long as the amplitudes are left unaltered.

Now, in order to test this law the circuit of figure 9 was used.

The first triode acts as an amplifier, while the second triode is used as a dynatron providing the negative resistance. Essentially this circuit is equivalent to the circuit of figure 10. The current through R represents an exact amplitude image (not phase image) of the grid potential of the first triode. The potential variations over R are grid potential variations of the third triode.

If the circuit of figure 9 is properly adjusted, the amplitudes of the various components of the sound spoken in the microphone are unaffected by a change of C, but their phases are. If, now, one listened to a loudspeaker connected to the

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(*) H. G. Möller, *Schwingungsaufgaben*, Hirzel, Leipzig, 1928, p. 43.

output side of the circuit of figure 9 while some one else spoke into the microphone set up in a different room, not the slightest difference would be observed after a pronounced change (up to 180° and, with a L inserted in series with the C, even 360°) of the phase of the components. This fact was verified by several persons, so that the above law of *Ohm* was found true for phase changes up to 360°. Obviously the microphone and the amplifier produced some phase changes already. The fact, however, that the phases of the higher components could be advanced as well as retarded, makes the above conclusion justified.

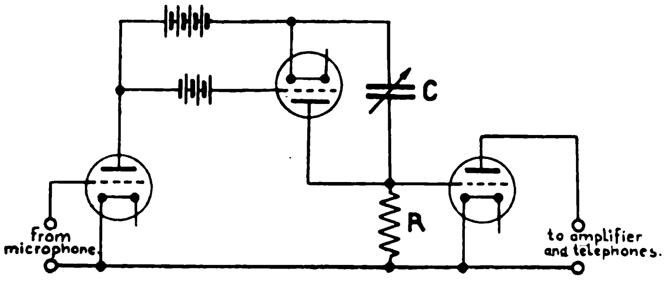

FIG. 9.

For *non-periodic* sounds such e. g. as the spoken language, phase retardation may be conceived of any amount extending beyond 360°. For instance, at the receiving end of a long telephone cable the time of arrival of the higher speach components may be considerably different from that of the lower components; this relative retardation may obviously amount to several periods. One cannot expect the ear to be absolutely insensitive to such long relative retardations, and practice with cables bears out this fact plainly.

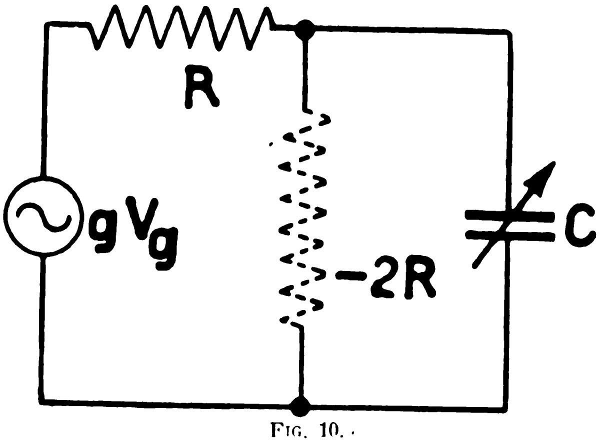

FIG. 10.

For *periodic* sounds (such as vowels) and normal amplitudes, however, the above experiments conclusively confirm the classical acoustical law of *Ohm*, which was also found to be valid for a periodic sounds (the spoken word) as long as the relative phase retardation between the high and low components was not greater than 360° of the high components.

Finally, oscillograms were taken of various vowels with and without changes of the relative phases, and the curves for the vowel *a* (the pronunciation in the Dutch language of this vowel is quite near that of the German language) is given in figure 11, where the lower oscillogram gives the undistorded vowel while the top one is phase-distorded (fundamental frequency $= 140 \text{ sec.}^{-1}$). It is curious to note that, though the wave-form of the two oscillograms is quite different, there is not the slightest difference audible. This oscillogram was taken by Mr. van der Mark of this laboratory, who in another article describes the technique of these experiments (where also further instances of vowel oscillograms will be found).

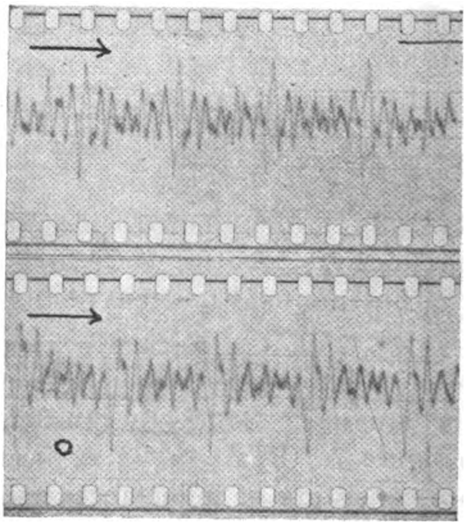

Fig. 11.

Eindhoven, Natuurkundig Laboratorium
der N. V. Philips' Gloeilampenfabrieken

ORIGINES DES TERMES GYROSCOPIQUES DANS LES ÉQUATIONS DES APPAREILS ÉLECTROMÉCANIQUES,

par PH. LE CORBEILLER.

Ingénieur en Chef des Télégraphes, Docteur ès Sciences.

SOMMAIRE. — *On montre que pour que les équations d'un système contiennent des termes gyroscopiques, il faut que l'expression de son énergie cinétique en fonction des coordonnées généralisées du système contienne des termes du premier degré dans les vitesses. Cela peut provenir analytiquement de ce que certaines de ces coordonnées sont ignorables; physiquement ceci correspond à des liaisons mécaniques sans frottement ou à des circuits électriques sans résistance. Mais on peut aussi, plus simplement, et sans négliger de résistances, faire la théorie des appareils monophasés à excitation continue en considérant leur mouvement comme une perturbation (une « modulation ») de l'état de repos mécanique dans lequel la* f. e. m. *continue d'excitation est la seule force appliquée. Les équations des appareils suivants sont formées à titre d'exemples : téléphone, haut-parleur électrodynamique, émetteur Fessenden, vibromètre, condensateur parlant.*

1. Les équations classiques du téléphone, données pour la première fois par Poincaré (L 2) (*) sont, sous la forme condensée que permet la notation symbolique

$$\left.\begin{aligned} z_2 v - Ai &= f \\ Av + Zi &= e \end{aligned}\right\} \quad (1)$$

v, i, f, e, sont respectivement la vitesse du centre du diaphragme, le courant téléphonique, la force mécanique et la force électromotrice appliquée, toutes quantités supposées sinusoïdales pures et de fréquence $\omega/2\pi$; z_2 est l'impédance mécanique z du diaphragme, corrigée, Z l'impédance électrique de l'enroulement téléphonique, A un coefficient constant.

Le fait que les termes Av, $-Ai$, ont des signes différents a souvent été relevé, et contrasté avec le fait que les termes analogues des équations du transformateur

$$\left.\begin{aligned} Z_1 i_1 + Z_{12} i_2 &= e_1 \\ Z_{12} i_1 + Z_2 i_2 &= e_2 \end{aligned}\right\}$$

sont de même signe. On appelle parfois ces termes de signes contraires, termes *gyroscopiques*. Les équations d'autres appareils, par exemple le haut-parleur Gaumont, présentent des mêmes termes de même forme. Je me propose de montrer quelle est l'origine de ces termes en mécanique, et comment des circonstances analogues les introduisent aussi en électromécanique. Je m'inspire surtout pour cet exposé de Thomson et Tait (L1) (**) que la question a particulièrement préoccupés, et de Winkelmann et Grammel (L6).

2. L'origine véritable de tous les termes de l'espèce se trouve dans l'accélération complémentaire que subit un point dans le mouvement relatif. On sait que si un point est en mouvement par rapport à un système lui-même en mouvement par rapport à un autre que l'on considère comme absolument fixe, l'accélération absolue du point est la somme de trois termes : l'accélération relative, l'accélération absolue du point coïncidant, et une accélération complémentaire dite de Coriolis. Celle-ci est égale au double du

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(*) Les chiffres précédés de la lettre L se rapportent à la liste placée à la fin de cette note.

(**) Tous les Anglais ont entre les mains ce qu'ils appellent le *ti and ti*, c'est-à-dire le traité de mécanique de Tait et Thomson. Il est peu d'ouvrages classiques qui contiennent tant de vues originales et profondes; il y a des théories qu'on ne trouve que là et que les ouvrages similaires du continent ne reproduisent pas, je ne sais pas pourquoi. Telle est la théorie des petits mouvements par le moyen des équations de Lagrange et Hamilton avec des applications à la stabilité des mouvements gyroscopiques, soit qu'on ne tienne pas, soit qu'on tienne compte du frottement... (POINCARÉ, *Savants et Écrivains :* Lord KELVIN.)

produit extérieur (ou vectoriel) de la vitesse relative du point par la rotation instantanée du système mobile. Prenons le cas le plus simple possible, celui d'un point de coordonnées $x\ (t)$, $y\ (t)$ par rapport à des axes rectangulaires Ox, Oy, tournant dans leur plan avec la vitesse angulaire constante ω.

Les projections sur les axes mobiles Ox, Oy, de l'accélération absolue du point sont :

$$\left.\begin{array}{l} x'' + 2\omega y' - \omega^2 x \\ y'' - 2\omega x' - \omega^2 y \end{array}\right\}$$

$$(\gamma \text{ rel} + \gamma \text{ Cor} + \gamma \text{ coïnc})$$

et nous voyons apparaître des termes gyroscopiques $2\omega y'$, $-2\omega x'$. Le caractère de ceux-ci est 1° d'être proportionnels aux vitesses ou, d'une manière générale, aux dérivées et coordonnées par rapport au temps; 2° que les coefficients des vitesses (non constants en général) forment un tableau *symétrique gauche*, c'est-à-dire tel que :

$$a_{ik} = -a_{ki}, \qquad a_{ii} = 0.$$

Tel est bien le cas ici, où les termes proportionnels aux vitesses sont

$$\left\{\begin{array}{r} 0\,.\,x' + 2\omega y' \\ -2\omega x' + 0\,.\,y', \end{array}\right. \quad \begin{array}{c} \text{leurs coefficients} \\ \text{formant le tableau} \end{array} \quad \left\|\begin{array}{cc} 0 & 2\omega \\ -2\omega & 0 \end{array}\right\|.$$

Nous saisissons sur ce cas élémentaire que les termes gyroscopiques ne sont que l'expression cartésienne de l'accélération de Coriolis.

Il en sera exactement de même si nous considérons le mouvement relatif dans l'espace; la rotation instantanée ω du système mobile ayant $(p,\ q,\ r)$ pour projections sur les axes fixes, les projections du double produit extérieur de ω $(p,\ q,\ r)$ par V_{rel} $(x',\ y',\ z')$ sont :

$$\left\{\begin{array}{lll} & 2ry' & -2qz' \\ -2rx' & & +2pz' \\ +2qx' & -2py' & \end{array}\right. \quad \begin{array}{c} \text{d'où} \\ \text{le tableau} \end{array} \quad \left\|\begin{array}{ccc} 0 & +2r & -2q \\ -2r & 0 & +2p \\ +2q & -2p & 0 \end{array}\right\|.$$

3. Cherchons sur ces deux exemples d'où seraient venus ces termes si nous avions appliqué la méthode de Lagrange. On sait que si T est l'énergie cinétique d'un système de points exprimée en fonction de leurs coordonnées q_1, q_2, ... q_i, les équations du mouvement du système sont

$$\frac{d}{dt}\left(\frac{\partial \text{T}}{\partial q'_i}\right) - \frac{\partial \text{T}}{\partial q_i} = \text{Q}_i$$

où Q_i est la force appliquée relative à la coordonnée q_i. Dans le cas du mouvement plan, on a l'expression suivante de T en fonction des coordonnées relatives

$$\text{T} = \frac{1}{2}\, m\, [x'^2 r y'^2 + 2\omega\,(yx' - xy') + \omega^2\,(x^2 + y^2)].$$

Les termes gyroscopiques provenaient donc des termes $\text{T}_1 = m\,\omega\ (yx' - xy')$, du premier degré dans les vitesses, comme il est aisé de s'en assurer. De même dans l'espace, les termes gyroscopiques provenaient des termes

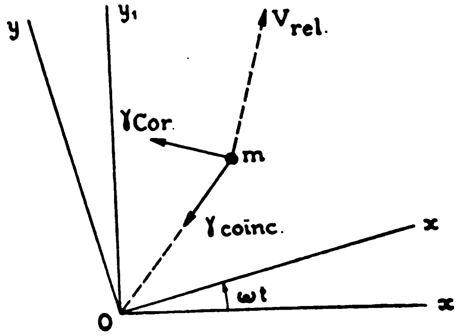

FIG. 1.

$$\text{T}_1 = m\,[p\,(zy' - yz') + q\,(xz' - zx') + r\,(yx' - xy')]$$

dans l'expression de T.

Plus généralement, s'il existe dans T un terme $\text{B}_{ik} q_i q'_k$ (*Bix* constant), ce terme fournira dans l'équation relative à la variable q_i un terme

$$\cdots - \frac{\partial \text{T}}{\partial q_i} = -\,\text{B}_{ik} q'_k$$

et dans l'équation relative à la variable q_k un terme

$$\frac{d}{dt}\left(\frac{\partial \text{T}}{\partial q'_k}\right) - \cdots = \text{B}_{ik}\, q'_i.$$

D'une manière tout à fait générale, s'il existe dans T des termes *du premier degré dans les vitesses*

$$\text{T}_1 = \text{B}_1 q'_1 + \text{B}_2 q'_2 + \cdots + \text{B}_i q'_i + \cdots$$

et que l'un au moins des coefficients B_i, fonctions des coordonnées q_1, q_2, ... contienne effectivement une coordonnée q_k autre que q_i, le terme correspondant, $B_1(q_2)\,q'_1$ par exemple, fournira dans les deux équations relatives aux variables q_1 et q_2 les termes

$$\frac{d}{dt}\left(\frac{\partial T}{\partial q'_1}\right) - \frac{\partial T}{\partial q_1} = \cdots + \frac{\partial B_1}{\partial q_2}\,q'_2 + \cdots$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial q'_2}\right) - \frac{\partial T}{\partial q_2} = \cdots + \frac{\partial B_1}{\partial q_2}\,q'_2 + \cdots$$

Ainsi *l'existence de termes gyroscopiques dans les équations d'un système est liée à la présence de termes du premier degré dans l'expression T de son énergie cinétique.*

4. Dans la mécanique des systèmes on a affaire à un certain nombre de corps solides assujettis à des liaisons. La méthode de Lagrange, sous sa forme originale, s'applique au cas où ces liaisons ne dépendent pas du temps, et s'expriment en termes finis. Dans ces conditions l'énergie cinétique T est une fonction *homogène* quadratique des vitesses généralisées q'_i. Il résulte que, en l'absence de termes du premier degré dans T, *il ne peut pas y avoir dans les équations de termes gyroscopiques.*

Pour que l'énergie cinétique T puisse contenir des termes du premier degré dans les vitesses, il faut donc que l'on s'écarte des conditions où s'est placé Lagrange. Ce sera le cas, notamment, si les coordonnées q_i cessent à elles seules de définir complètement le mouvement du système.

On rencontre effectivement des termes gyroscopiques lorsqu'on se pose des problèmes des genres suivants :

a) On cherche le mouvement du système *relativement* à un système de référence lui-même en mouvement (Exemple: le mouvement d'un point relativement à des axes tournants) (par. 2).

b) Les liaisons dépendent du temps (*liaisons* dites *cinétiques*); ce cas généralise le précédent.

c) On cherche les *petites perturbations du mouvement stable d'un système*, lorsqu'on lui applique de petites percussions ou de petites forces données. Les nouvelles coordonnées étant alors les petites variations des anciennes, lesquelles sont supposées connues en fonction du temps, on voit qu'il s'agit ici encore d'un problème de mouvement relatif généralisé.

d) On cherche à connaître en fonction du temps quelques-unes seulement des coordonnées du système. Il n'est pas possible en général de s'occuper ainsi de certaines coordonnées, en éliminant les autres; un cas où cela est possible, est celui où les coordonnées laissées de côté satisfont à certaines conditions; elles sont dites alors « cachées » ou « ignorables ». Nous allons examiner ce dernier cas de plus près.

5. Il peut arriver qu'une certaine coordonnée q_i d'un système ne figure pas par elle-même, mais seulement par sa dérivée q'_i, dans l'expression de l'énergie cinétique T du système. On dit que q_i est une coordonnée *cyclique* (parce que telle est notamment la coordonnée angulaire φ qui détermine la position d'un solide de révolution autour de son axe; T contient au moins un terme $\frac{1}{2}\,C\varphi'^2$, C moment d'inertie, mais en général ne dépend pas de φ). Si de plus la force appliquée Q_i relative à q_i est nulle, on dit que q_i est une coordonnée *cachée* ou *ignorable*. On peut alors obtenir des équations du type de Lagrange où ne figure plus la variable q_i.

Supposons par exemple que le système dépende de trois coordonnées q_1, q_2, q_3 qui le définissent entièrement. L'énergie cinétique est homogène quadratique en q'_1, q'_2, q'_3 :

$$T = \frac{1}{2}A_1q_1'^2 + \frac{1}{2}A_2q_2'^2 + \frac{1}{2}A_3q_3'^2 + B_1q'_2q'_3 + B_2q'_3q'_1 + B_3q'_1q'_2.$$

Supposons que la variable q_3 soit ignorable. Les A et B sont alors fonctions de q_1, q_2 et peut-être t, mais non de q_3, et la force Q_3 est nulle. L'équation de Lagrange relative à q_3

$$\frac{d}{dt}\left(\frac{\partial T}{\partial q'_3}\right) - \frac{\partial T}{\partial q_3} = Q_3$$

est donc ici

$$\frac{d}{dt}\left(\frac{\partial T}{\partial q'_3}\right) = 0$$

d'où une intégrale première

$$\frac{\partial T}{\partial q'_3} = A_3q'_3 + B_1q'_2 + B_2q'_1 = \text{const} = \Phi.$$

On forme alors la *fonction de Routh*

$$\begin{aligned} R &= T - \Phi q'_3 \\ &= \frac{1}{2}A_1q_1'^2 + \frac{1}{2}A_2q_2'^2 + B_3q'_1q'_2 - \frac{1}{2}A_3q_3'^2 \\ &= \frac{1}{2}A_1q_1'^2 + \frac{1}{2}A_2q_2'^2 + B_3q'_1q'_2 - \frac{1}{2A_3}(\Phi - B_2q'_1 - B_1\,q_2'^2). \end{aligned}$$

Routh a démontré (voir par exemple Pomey [L3], p. 71) que si l'on traite la fonction R (q'_1, q'_2) comme l'énergie cinétique d'un système, on obtient, sans changer les forces appliquées Q_1 et Q_2, des équations

$$\left.\begin{aligned} \frac{d}{dt}\left(\frac{\partial R}{\partial q'_1}\right) - \frac{\partial R}{\partial q_1} = Q_1 \\ \frac{d}{dt}\left(\frac{\partial R}{\partial q'_2}\right) - \frac{\partial R}{\partial q_2} = Q_2 \end{aligned}\right\} \qquad (2)$$

qui donnent correctement, en fonction du temps, les coordonnées q_1, q_2 de notre système (q_1, q_2, q_3); mais la coordonnée ignorable q_3 a disparu.

Or il est très remarquable que R n'est plus homogène quadratique dans les vitesses; il est décomposable en $R_2 + R_1 + R_0$, et on a en particulier :

$$R_1 = \frac{\Phi}{A_3} A_1 q'_1 + \frac{\Phi}{A_3} A_2 q'_2.$$

Les équations (2) contiendront donc en général des termes gyroscopiques.

6. Le *gyroscope* est précisément un système de ce genre, du moins tel qu'il est ordinairement conçu et employé (*); d'où l'expression « termes gyroscopiques ». Vérifions-le. Soient ψ, θ et φ ses coordonnées (angles d'Euler : ψ précession, θ nutation, φ rotation propre), $A = B$ et C ses moments d'inertie principaux; on a :

$$2T = Ap^2 + Bq^2 + Cr^2 = A(\theta'^2 + \psi'^2 \sin^2\theta) + C(\psi' \cos\theta + \varphi')^2.$$

Les coordonnées ψ et φ sont donc *cycliques*. On suppose qu'il n'y a ni frottements, ni liaisons élastiques. En général, il n'y a pas de couple appliqué ayant pour axe l'axe du gyroscope; la coordonnée φ est donc *ignorable*, mais non ψ. La troisième équation de Lagrange est :

$$\frac{d}{dt} C(\psi' \cos\theta + \varphi') = 0$$

d'où

$$C(\psi' \cos\theta + \varphi') = \text{const} = \Phi$$

(ce que donnerait directement le théorème du moment de la quantité de mouvement); la fonction de Routh est :

$$\begin{aligned} R &= T - \Phi\varphi' \\ &= \frac{1}{2} A(\theta'^2 + \psi'^2 \sin^2\theta) + \frac{1}{2} C\psi'^2 \cos^2\theta - \frac{1}{2} C\varphi'^2 \\ &= \frac{1}{2} A\theta'^2 + \frac{1}{2}(A \sin^2\theta + C \cos^2\theta)\psi'^2 - \frac{1}{2C}(\Phi - C\cos\theta . \psi')^2 \end{aligned}$$

d'où

$$R_2 = \frac{1}{2} A\theta'^2 + \frac{1}{2} A \sin^2\theta . \psi'^2, \qquad R_1 = \Phi \cos\theta . \psi';$$

on a donc les deux équations en ψ et θ

$$\left.\begin{aligned} \frac{d}{dt}\left(\frac{\partial R_2}{\partial \psi'}\right) - \frac{\partial R_2}{\partial \psi} - \Phi \sin\theta . \theta' = Q_\psi \\ \frac{d}{dt}\left(\frac{\partial R_2}{\partial \theta'}\right) - \frac{\partial R_2}{\partial \theta} + \Phi \sin\theta . \psi' = Q_\theta \end{aligned}\right\}$$

où les termes gyroscopiques sont en évidence (**).

7. Jusqu'ici nous avons utilisé uniquement le langage de la mécanique analytique; mais tout ce que nous avons dit s'applique à des systèmes électromécaniques, dans la mesure où l'on peut considérer, suivant l'idée de Maxwell, la quantité d'électricité qui traverse à l'instant t une section fixe d'un conducteur linéaire comme une coordonnée de Lagrange, le courant i comme sa vitesse, l'énergie électromagnétique comme une énergie cinétique et l'énergie électrostatique comme une énergie potentielle. Nous allons appliquer les théories qui précèdent à quelques appareils électromécaniques; il n'est pas douteux qu'elles n'aient un champ d'application beaucoup plus étendu.

8. La *théorie du récepteur téléphonique par Poincaré* (L 2) offre un exemple de l'emploi de variables cachées. Un récepteur téléphonique comporte un aimant permanent. Or les systèmes considérés par Maxwell ne contenaient pas d'aimants. Poincaré se propose de généraliser les équations de Lagrange-Maxwell et de montrer qu'elles subsistent lorsque le système comprend des aimants, permanents ou non. A cet effet, il

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(*) Cette restriction vise les appareils gyroscopiques *asynchrones* de M. Salomon (L 8).

(**) L'analogie de ces équations et de celles d'un alternateur (ou moteur *synchrone*) rotatif a conduit M. Salomon à la construction d'un remarquable modèle mécanique d'un alternateur, comprenant un gyroscope (L 8).

considère un aimant comme constitué par un grand nombre de courants particulaires (Ampère) qui n'ont ni résistance, ni capacité et qui ne contiennent pas de *f. e. m.* Dans ces conditions, les variables q relatives à ces courants n'entrent dans l'énergie potentielle que par leurs dérivées, les forces appliquées sont nulles et toutes ces variables sont des variables cachées. Elle s'éliminent toutes à la fois lorsqu'on forme la fonction de Routh, $R = T - \Sigma \Phi_i q'_i$, dont Poincaré donne les propriétés, et il ne reste plus dans le cas du récepteur téléphonique que les deux variables électrique et mécanique d'entrée et de sortie du système liées par les équations (1). Nous avons donc là un exemple de termes gyroscopiques obtenus par la voie (*d*) (par. 4).

Sous l'influence de cet exemple célèbre, on pourrait croire que ce sont des variables cachées qui expliqueront en général la présence de termes gyroscopiques dans les équations des appareils électromécaniques. Cela ne serait pas exact. En effet, dès qu'on abandonne les courants particulaires, qui par hypothèse ne rencontrent aucune résistance, pour étudier les courants de l'électrotechnique ordinaire, par exemple lorsqu'on remplace dans un schéma d'appareil un aimant permanent par un électro-aimant, on doit mettre dans les seconds membres des équations de Lagrange des chutes ohmiques de tension de la forme $-Rq'$, et la variable q correspondante cesse d'être une variable cachée.

Il se trouve que les équations de telles machines s'obtiennent en toute rigueur par une méthode bien plus simple que celle des variables cachées, comme nous allons le montrer sur un exemple. Et les termes gyroscopiques proviennent de la cause (*c*) que nous signalions plus haut : c'est que l'on étudie les petits mouvements d'un système autour d'un mouvement stable.

9. Nous poserons les hypothèses suivantes. L'appareil que nous examinons est un appareil *électromécanique oscillant monophasé, à excitation continue.* Il comporte sous sa forme type trois degrés de liberté, ou trois coordonnées : 1° Une coordonnée mécanique x qui définit la position d'un organe mécanique oscillant (non pas tournant); 2° Une coordonnée électrique q_1 relative à un circuit magnétisant, alimenté par une source continue (batterie ou dynamo); 3° Une coordonnée électrique q_2 relative à un circuit électrique destiné à porter un courant alternatif. Nous appellerons ces deux circuits, circuit d'excitation et circuit alternatif. Le circuit d'excitation joue un rôle essentiel, mais auxiliaire; la machine est destinée à fournir de l'énergie mécanique par l'intermédiaire de son organe oscillant (piston, diaphragme...), lorsqu'on lui fournit de l'énergie électrique de même fréquence à ses bornes ou inversement; les deux cas se distingueraient par des conventions de signes que nous n'aurons pas besoin de préciser.

Cela étant, le fonctionnement de la machine sera défini par les expressions :

1° de son énergie cinétique T,

$$T = \frac{1}{2} m x'^2 + \frac{1}{2} L_1 q_1'^2 + M q_1' q_2' + \frac{1}{2} L_2 q_2'^2;$$

L_1, M et L_2 sont trois fonctions de x, que la description matérielle de la machine permettrait de calculer (certaines pouvant être constantes); c'est en cela que consiste le couplage entre les parties mécanique et électrique de l'appareil;

2° de sa fonction de dissipation F,

$$F = \frac{1}{2} r x'^2 + \frac{1}{2} R_1 q_1'^2 + R_2 q_2'^2;$$

nous supposons la résistance mécanique r et les résistances électriques R_1 et R_2 constantes;

3° de son énergie potentielle V,

$$V = \frac{1}{2} r x^2 + \frac{1}{2} \frac{q^2}{C};$$

nous supposons qu'il n'y a pas de capacité dans le circuit d'excitation, et que les coefficients s (raideur) et C (capacité dans le circuit alternatif) sont constants.

Les trois équations de Lagrange sont :

$$\left.\begin{aligned}
m x'' - \frac{1}{2} \frac{dL_1}{dx} q_1'^2 - \frac{dM}{dx} q_1' q_2' - \frac{dL_2}{dx} q_2' &= f - r x' - s x \\
\frac{d}{dt}(L_1 q_1' + M q_2') &= e_1 - R_1 q_1' \\
\frac{d}{dt}(M q_1' + L_2 q_2') &= e_2 - R_2 q_2' - \frac{q_2}{C}
\end{aligned}\right\}$$

où f, e_1, e_2 sont les forces extérieures appliquées.

10. J'examine d'abord un premier état de l'appareil; dans ce premier état j'applique une *f. e. m.* continue E au circuit d'excitation et aucune autre force f (mécanique) ou e_2 (électrique). L'appareil sera mécaniquement au repos. Mais il passera dans le circuit d'excitation un courant continu i_0 et l'organe mécanique sera attiré à une distance x_0 de sa position d'équilibre propre; ces deux quantités étant données par

$$\left.\begin{aligned} -\frac{1}{2}\left(\frac{dL_1}{dx}\right)_{x=x_0}\cdot i_0^2 &= -sx_0 \\ 0 &= E - R_1 i_0 \end{aligned}\right\} \qquad (3)$$

qui est ce que deviennent la première et la deuxième équation; la troisième est alors vérifiée identiquement.

Cet état de *repos apparent* est, pour la théorie de Lagrange-Maxwell, un état de *mouvement*, puisque la coordonnée q_1 a une vitesse i_0 non nulle. C'est là la circonstance paradoxale d'où vont sortir nos termes gyroscopiques.

Cherchons, en effet, quelles sont les petites déviations du système à partir de ce premier état de mouvement si l'on impose des *formes alternatives très petites* f et e à l'organe mécanique et au circuit alternatif. Développons pour cela les fonctions de x, L_1, M et L_2 autour de x_0, et posons :

(Circuit d'excitation)

$$L_1(x_0+\xi) = L_1 + A_1\xi + A_2\xi^2 + \cdots$$

(Couplage électrique)

$$M(x_0+\xi) = M + B_1\xi + \cdots$$

(Circuit alternatif)

$$L_2(x_0+\xi) = L_2 + \cdots$$

Nous aurons pour nouvelle coordonnée mécanique ξ, et pour vitesse de la nouvelle coordonnée du circuit d'excitation, $i_1 = q_1 - i_0$. La coordonnée q_2 n'a pas changé; posons pour la symétrie $i = \frac{dq_2}{dt}$. Formons la nouvelle énergie cinétique, et ne conservons que les termes du second degré au plus dans les nouvelles variables; de cette manière les équations du système ne contiendront que les termes du premier degré dans les variables, les suivants étant supposés négligeables. Il vient :

$$\begin{aligned} T &= \frac{1}{2}m\xi'^2 + \frac{1}{2}L_1(x_0+\xi)\,.\,(i_0+i_1)^2 \\ &\quad + M(x_0+\xi)\,.\,(i_0+i_1)\,i + \frac{1}{2}L_2(x+\xi)\,.\,i^2 \\ &= \frac{1}{2}L_1 i_0^2 + \left(L_1 i_0 i + \frac{1}{2}A_1 i_0^2\xi + M i_0 i\right) \\ &\quad + \left(A_1 i_0\xi i_1 + B_1 i_0 \xi i + \frac{1}{2}A_2 i_0^2\xi^2\right) \\ &\quad + \left(\frac{1}{2}m\xi'^2 + \frac{1}{2}L_1 i_1^2 + M i_1 i + \frac{1}{2}L_2 i_2^2\right) + \cdots \end{aligned}$$

La nouvelle expression T contient donc maintenant des termes du premier degré dans les nouvelles vitesses, les termes

$$A_1 i_0 \xi i_1 \qquad \text{et} \qquad B_1 i_0 \xi i.$$

Ecrivons les équations de Lagrange :

$$\left.\begin{aligned} m\xi'' - A_1 i_0 i - B_1 i_0 i - A_2 i_0^2\xi - \frac{1}{2}A_1 i_0^2 &= f - r\xi' - sx_0 - s\xi \\ L\frac{di_1}{dt} + M\frac{di}{dt} + A_1 i_0 \xi' &= E - R_1 i_0 - R_1 i_1 \\ M\frac{di_1}{dt} + L_2\frac{di}{dt} + B_1 i_0 \xi' &= e - R_2 i - \frac{q_2}{C}. \end{aligned}\right\}$$

En vertu des équations (3) de l'état de mouvement qui sert de référence, les deux premières se simplifient. Posons encore pour abréger :

$$A_1 i_0 = A, \qquad B_1 i_0 = B, \qquad A_2 i_0^2 = s_1,$$

il vient

$$\left.\begin{aligned} m\xi'' + r\xi' + (s-s_1)\xi \quad & - A i_1 \quad - B i = f \\ A\xi' \quad & + L_1\frac{di}{dt} + R_1 i_1 + M\frac{di}{dt} = 0 \\ B\xi' \quad & + M\frac{di}{dt} \quad + L_2\frac{di}{dt} + R_2 i + \frac{q_2}{C} = e, \end{aligned}\right\}$$

ce qui s'écrit enfin, avec des notations évidentes,

$$\left.\begin{aligned} z_2 v - A i_1 - B i &= f \\ A v + Z_1 i_1 + jM\omega i &= 0 \\ B v + jM\omega i_2 + Z_2 i &= e. \end{aligned}\right\}$$

Dans ce système, les variables, toutes alternatives et de pulsation ω, sont, d'une part, la vitesse v du mouvement de l'organe mécanique autour de sa position d'équilibre relatif x_0, les variations i_1 du courant d'excitation autour du courant d'excitation moyen i_0, et le courant inducteur (ou induit) i; d'autre part, la force et la *f. e. m.* appliquées (ou produites) f et e. Le système est linéaire par rapport à ces cinq variables, et à une fréquence donnée, tous les coefficients sont des constantes complexes $\alpha = a + ja'$, de sorte que si y et z sont deux quelconques des cinq variables, les trois autres s'expriment en fonction de celles-ci supposées connues sous la forme simple $\alpha y + \beta z$; α et β, constantes complexes, sont des impédances ou des admittances généralisées.

Il est intéressant d'éliminer i_1 entre ces équations; l'on obtient ainsi le système

$$\left.\begin{aligned} \left(z_2 + \frac{A_2}{Z_1}\right)v - \left(B - j\omega\frac{MA}{Z_1}\right)i &= f \\ \left(B - j\omega\frac{MA}{Z_1}\right)v + \left(Z + \frac{M^2\omega^2}{Z_1}\right)i &= e \end{aligned}\right\}$$

sur lequel on voit nettement l'influence de l'excitation sur l'organe oscillant et sur le circuit alternatif :

1° l'impédance z de l'organe oscillant est modifiée par l'adjonction des termes

$$j\frac{A_2 i_0^2}{\omega} + \frac{A_1^2 i_0^2}{Z_1};$$

2° les deux variables, mécanique et électrique, sont couplées, les coefficients des termes de couplage étant

$$\pm\left(B_1 i_0 - j\omega\frac{MA_1 i_0}{Z_1}\right);$$

3° l'impédance Z du circuit alternatif est modifiée par l'adjonction du terme

$$\frac{M^2\omega^2}{Z_1}.$$

On a donc pour équations de cette sorte de quadripôle électromécanique, à une fréquence donnée,

$$\left.\begin{aligned} (z + \alpha i_0^2)v - \beta i_0 . i &= f \\ \beta i_0 . v + (Z + \gamma)\, i &= e \end{aligned}\right\} \qquad (4)$$

α, β, γ, sont des constantes complexes, dont les deux extrêmes peuvent être nulles. On voit que *la correction de l'impédance mécanique, si elle existe, est proportionnelle au carré du courant moyen d'excitation* (*), *tandis que le couplage est proportionnel à ce courant, et que la correction de l'impédance électrique n'en dépend pas.*

On peut dans cet énoncé remplacer le courant d'excitation i_0 par la tension continue E de la source excitatrice (puisque $E = R_1 i_0$).

12. Enfin, si l'on élimine encore une des deux variables i et v, on obtient une seule équation dont le coefficient unique, en cas de court-circuit mécanique ou électrique (f ou $e = 0$), a une signification importante pour le fonctionnement de l'appareil. On obtient ainsi :

$$e = \frac{\beta^2 i_0^2 + (Z + \gamma)(z + \alpha i_0^2)}{z + \alpha i_0^2}\, i,$$

ou bien

$$e = -\frac{\beta^2 i_0^2 + (Z + \gamma)(z + \alpha i_0^2)}{\beta i_0}\, v.$$

Le coefficient de i est l'impédance électrique d'entrée de l'appareil, point de départ de l'étude de son fonctionnement comme moteur électrique à courant ou à potentiel constant. (On définirait de même une impédance mécanique d'entrée, pour servir à l'étude du fonctionnement en générateur électrique.) Le coefficient de v est l'impédance électromécanique de transfert. Si l'on admet que la charge mécanique de l'appareil, alimenté à potentiel constant, est constituée par une résistance mécanique constante r_{ext} que l'on a fait rentrer dans le coefficient r de z, la puissance utile recueillie est $\frac{1}{2}\, r_{\text{ext}}\, |v|^2$, et varie par conséquent, pour différents courants d'excitation i_0, en sens inverse du module de l'impédance de transfert. Or, ce dernier est infini pour i_0 nul ou pour i_0 infini; il y a donc une valeur optimum pour le courant i_0 ou la tension E d'excitation, comme l'a fait remarquer M. Lichte (L 4). Bien que l'étude des propriétés de ce type d'appareils soit en dehors du cadre de la présente note, nous avons indiqué celle-ci pour montrer le genre d'application qui a été fait des équations que nous commentons, et éviter qu'elles apparaissent comme un exercice purement formel.

13. Nous allons, à titre d'exemples, expliciter par la méthode précédente les équations de quel-

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(*) On s'explique que ce terme soit si important dans les haut-parleurs électromagnétiques.

ques appareils. Commençons par le téléphone ordinaire, qui est le prototype des moteurs électromagnétiques de nombreux haut-parleurs. Nous envisagerons un seul circuit électrique, mais dans ce circuit nous superposerons la *f. e. m.* continue d'excitation E et la *f. e. m.* téléphonique alternative *e*. L'énergie cinétique du système est :

$$T = \frac{1}{2} m x'^2 + \frac{1}{2} L(x) q'^2.$$

Dans le premier état de l'appareil, nous supposons que E est la seule *f.e.m.* appliquée (ni *f.e.m.* alternative *e*, ni force appliquée au diaphragme). Le centre du diaphragme est alors attiré d'une quantité x_0. Nous poserons

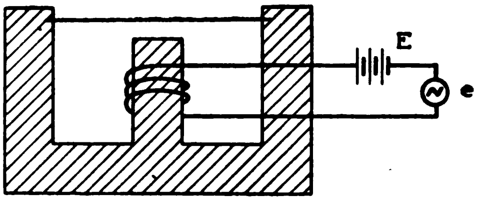

FIG. 2.

$$L(x_0 + \xi) = L + A_1\xi + A_2\xi^2 + \cdots$$

et nous aurons pour équations du premier état

$$-\frac{1}{2} A_1 i_0^2 = -S x_0, \qquad 0 = E - R i_0.$$

Dans le second état nous appliquerons en plus de E les forces alternatives *f* et *e* et nous rapporterons les élongations à l'abcisse x_0, les courants au courant i_0. L'énergie cinétique devient

$$T = \frac{1}{2} L i_0^2 + \left(L i_0 i + \frac{1}{2} A_1 i_0^2 \xi\right) + \left(\frac{1}{2} m v^2 + \frac{1}{2} L i^2 + A_1 i_0 \xi i + \frac{1}{2} A_2 i_0^2 \xi^2\right) + \cdots$$

et les équations sont, en ne conservant que les termes du premier degré

$$\left.\begin{array}{ll} m\dfrac{dv}{dt} - A_1 i_0 i - A_2 i_0^2 \xi - \dfrac{1}{2} A_1 i_0^2 & = f - rv - s x_0 - s\xi \\ L\dfrac{di}{dt} + A_1 i_0 v & = E + e - R i_0 - R i \end{array}\right\}$$

ce qui se simplifie en

$$\left.\begin{array}{l} z_2 v - A i = f \\ A v + Z i = e \end{array}\right\}$$

qui sont les équations (1) classiques.

14. Passons aux moteurs de haut-parleurs dits électrodynamiques (Gaumont, par exemple). Ici, il faut supposer le circuit d'excitation et le circuit alternatif distincts. La théorie est donc exactement celle que nous avons faite au par. 10.

Toutefois $L_1(x)$ est indépendant de x; c'est sur la variation de $M(x)$ que repose l'appareil (coefficient B).

Nous avons donc $A_1 = A_2 = 0$, $A = 0$, $z_2 = z$, et les équations sont

$$\left.\begin{array}{r} zv \qquad\qquad - Bi = f \\ Z_1 i_1 + jM\omega i = 0 \\ Bv + jM\omega i_1 + Zi = e \end{array}\right\}$$

Eliminant le courant d'excitation i_1 il vient :

$$\left.\begin{array}{ll} zv - Bi & = f \\ Bv + \left(Z + \dfrac{M^2\omega^2}{Z_1}\right) i & = e. \end{array}\right\}$$

Comme Z_1 est principalement une inductance $\gamma L_1 \omega$, on voit qu'en posant

$$Z_2 = j\left(L - \frac{M^2}{L_1}\right)\omega + R - \frac{j}{C\omega}$$

les équations du haut-parleur électrodynamique s'écrivent

$$\left.\begin{array}{l} zv - Bi = f \\ Bv + Z_2 i = e, \end{array}\right\}$$

et présentent une symétrie assez curieuse avec celles du haut-parleur électromagnétique : dans l'un, l'impédance mécanique est seule modifiée, et par diminution de la raideur; dans l'autre, l'impédance électrique est seule modifiée, et par diminution de la self-induction.

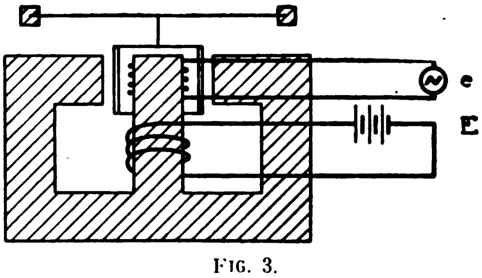

FIG. 3.

15. Examinons l'émetteur sonore sous-marin de Fessenden. Ici le circuit alternatif est fixe, et le diaphragme est solidaire d'un cylindre de cuivre mobile suivant son axe qui constitue un troi-

sième enroulement, constamment en court-circuit. Il y a donc quatre degrés de liberté, dont un mécanique. Dans le premier état, nous supposerons que E est la seule *f. e. m.* appliquée. Bien qu'il n'y ait pas alors d'attraction du diaphragme, la simple modification de l'expression de l'énergie cinétique résultant de ce que l'on rapporte le courant dans le circuit d'excitation à sa valeur moyenne i_0, sans toucher en rien aux autres coordonnées ni à leurs vitesses, va suffire à introduire des termes de couplage gyroscopiques. Cette énergie cinétique est

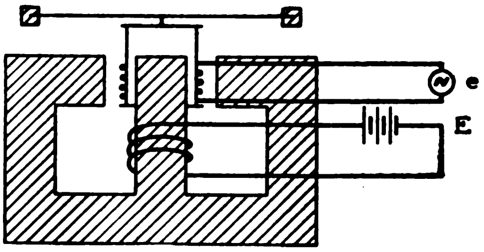

FIG. 4.

$$T = \frac{1}{2}mv^2 + \frac{1}{2}L_1(i_0 + i_1)^2 + \frac{1}{2}L_2 i_2^2 + \frac{1}{2}L_3 i_3^2$$
$$+ M_{23}(x)i_2 i_3 + M_{13}(x)(i_0 + i_1)i_3 + M_{12}(i_0 + i_1)i_2.$$

où seuls les coefficients d'induction mutuelle M_{23} et M_{13} dépendent de x. Mais comme nous ne voulons garder que les termes du second degré au plus, nous voyons que le terme constant dans le développement de $M_{23}(x)$ va seul intervenir, de sorte que l'appareil repose sur la variation de $M_{13}(x)$ seul. Posant donc

$$M_{13}(x_0 + \xi) = M_{13} + C\xi + \cdots$$

les termes intéressants dans le développement de T sont :

$$T = \frac{1}{2}mv^2 + \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + \frac{1}{2}L_3 i_3^2$$
$$+ M_{23}i_2 i_3 + M_{13}i_1 i_3 + M_{12}i_1 i_2 + Ci_0 x i_3 + \cdots$$

et les équations reliant les trois courants alternatifs i_1, i_2, i_3 et l'élongation alternative x sont:

$$\left.\begin{aligned} zv \qquad\qquad\qquad\quad - Ci_0 i_3 &= f \\ Z_1 i_1 + jM_{12}\omega i_2 + jM_{13}\omega i_3 &= 0 \\ jM_{12}\omega i_1 + Z_2 i_2 + jM_{23}\omega i_3 &= e \\ Ci_0 v + jM_{13}\omega i_1 + jM_{23}\omega i_3 + Z_3 i_3 &= 0. \end{aligned}\right\} \quad (5)$$

Le lecteur qui aura eu la patience de nous suivre jusqu'ici conviendra sans doute que ces équations pouvaient être posées au vu de la figure sans aucun calcul. Les trois circuits électriques sont couplés entre eux; le circuit qui est lié à l'organe mécanique est le troisième, et le coefficient de couplage est proportionnel au courant d'excitation moyen i_0. A droite, nous mettons les forces alternatives appliquées. Dans cette question comme dans bien d'autres, le difficile était de résoudre le problème sous son aspect le plus simple (étude du téléphone par Poincaré); le modèle une fois donné, il n'y a aucune difficulté à écrire les équations d'un appareil du même type, même beaucoup plus compliqué.

Pour l'étude ultérieure du Fessenden, il faut naturellement éliminer i_1 et i_3 de manière à avoir les équations du quadripôle électromécanique; ces équations ont la forme (4) déjà signalée.

16. Le remarquable appareil de mesure de MM. Nukiyama et Matsudaira, le *vibromètre* (L 5), a un circuit d'excitation, deux circuits alternatifs et un organe mécanique vibrant, et les deux circuits alternatifs sont liés à l'organe mécanique; les équations de l'appareil sont donc les équations (5), avec en plus deux termes Bi_2 et Bv. Les auteurs ne s'étant pas, à juste titre, préoccupés de l'ondulation du courant d'excitation, trouvent un système de trois équations, pleinement suffisant au point de vue pratique. Les remarques de ces auteurs sur leur appareil méritent la plus grande attention.

17. Ainsi qu'on l'a vu en traitant successivement du téléphone et du Fessenden, et comme il est bien clair analytiquement, on introduit des termes du premier degré dans les vitesses dans l'expression de T, condition nécessaire pour qu'il y ait des termes gyroscopiques, en étudiant

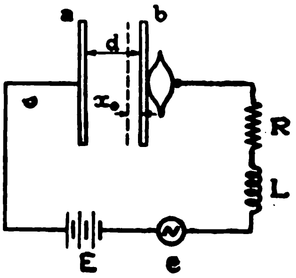

FIG. 5.

les petites vibrations du système autour d'un état *de mouvement;* si pour des appareils ne rentrant pas dans le schéma que nous avons posé au § 9, le premier état, état de référence, ne comporterait pas de mouvement pour l'un au moins des degrés de liberté, il ne servirait de rien qu'il comportât des déviations permanentes : nous n'obtiendrons pas de termes gyroscopiques. Nous n'en donnerons qu'un exemple, espérant revenir plus tard d'une manière plus générale sur cette classe d'appareils. Considérons un haut-parleur électrostatique ou *condensateur parlant* : *a* est l'armature fixe, *b* l'armature mobile de masse *m* liée à un ressort. L'énergie cinétique du système est

$$T = \frac{1}{2} m x'^2 + \frac{1}{2} L q'^2,$$

la fonction de dissipation

$$F = \frac{1}{2} r x'^2 + \frac{1}{2} R q'^2$$

et l'énergie potentielle

$$V = \frac{1}{2} s x^2 + \frac{1}{2} \frac{q^2}{C(x)}.$$

Les équations de Lagrange sont

$$\left.\begin{aligned} m\frac{dv}{dt} &= f - rv - sx + \frac{q^2}{2}\frac{C'(x)}{[C(x)]^2} \\ L\frac{di}{dt} &= E + e - Ri - \frac{q}{C(x)}. \end{aligned}\right\}$$

Appelant *d* la distance des armatures lorsque aucune *f.e.m.* n'est appliquée, et comptant x positif dans le sens de *b* vers *a*, on a

$$C(x) = \frac{kS}{4\pi(d - x)},$$

$$\frac{C'(x)}{[C(x)]^2} = \frac{4\pi}{kS}.$$

Les équations ci-dessus s'écrivent donc :

$$\left.\begin{aligned} m\frac{dv}{dt} &= f - rv - sx + \frac{2\pi}{kS} q^2 \\ L\frac{di}{dt} &= E + e - Ri - \frac{4\pi}{kS} q(d - x). \end{aligned}\right\}$$

Je considère un premier état du système dans lequel j'applique seulement la *f.e.m.* continue E; les armatures se sont rapprochées de la quantité x_0, et on a pour l'équilibre :

$$\left.\begin{aligned} 0 &= 0 - sx_0 + \frac{2\pi}{kS} q_0^2 \\ 0 &= E - \frac{4\pi}{kS} q_0 (d - x_0). \end{aligned}\right\} \qquad (6)$$

Ces deux équations définissent x_0 et q_0, et non linéairement; mais q_0 dépend d'une équation du troisième degré qui n'a qu'une racine, ce qui détermine x_0.

Cela étant, je rapporte le système en mouvement à ce premier état, ce qui revient à un déplacement d'origine pour chacune des variables; je pose

$$x = x_0 + \xi, \qquad q = q_0 + \eta, \qquad \frac{4\pi(d - x_0)}{kS} = C_0.$$

L'expression de l'énergie cinétique ne change pas; T continuant à être homogène quadratique dans les vitesses, il n'y aura pas de termes gyroscopiques. F ne change pas non plus. L'énergie potentielle devient :

$$\begin{aligned} V &= \frac{1}{2} s(x_0 + \xi)^2 + \frac{2\pi}{kS}(d - x_0 - \xi)(q_0 + \eta)^2 \\ &= \frac{1}{2} s x_0^2 + \frac{2\pi}{kS}(d - x_0) q_0^2 \\ &\quad + s x_0 \xi + \frac{4\pi}{kS}(d - x_0) q_0 \eta - \frac{2\pi}{kS} q_0 \xi \\ &\quad + \frac{1}{2} s \xi^2 + \frac{2\pi(d - x_0)}{kS} \eta^2 - \frac{4\pi}{kS} q_0 \xi \eta + \cdots \end{aligned}$$

en nous limitant aux termes du second degré. Formant les équations de Lagrange et tenant compte des équations (6) du premier état, il vient

$$\left.\begin{aligned} m\frac{dv}{dt} &= f - rv - s\xi + \frac{4\pi q_0}{kS}\eta \\ L\frac{di}{dt} &= C - \frac{\eta}{C_0} + \frac{4\pi q_0}{kS}\xi \end{aligned}\right\}$$

ou bien

$$\left.\begin{aligned} zv + \frac{jA}{\omega} i &= f \\ \frac{jA}{\omega} + Z_0 i &= e, \end{aligned}\right\}$$

en posant $A = \frac{4\pi q_0}{kS} = \frac{E}{d - x_0}$, et Z_0 étant l'impédance du circuit électrique dans le premier état (capacité C_0). Ici, les termes gyroscopiques étant absents, les coefficients de couplage sont égaux entre eux et à une réactance pure. On lira avec intérêt une étude de M. de Goer (L 7) sur ces dernières équations.

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SUR DES PROPRIETES COMMUNES A DIVERS PHENOMENES D'OSCILLATION ET SUR DES ANALOGIES GYROSCOPIQUES DES PHENOMENES ELECTROMAGNETIQUES

par BERNARD SALOMON,
Ingénieur des Télégraphes.

Sommaire. — INTRODUCTION : Les analogies mathématiques. Analogies du champ magnétique et du vecteur-rotation, qui sont l'un et l'autre des vecteurs axiaux. — La loi fondamentale de l'induction et le théorème des moments cinétiques.

I. *Machines synchrones :*

A) La notion générale d' « excitation » en énergétique et le gyroscope.

B) Alternateur monophasé — couples et vitesses complexes — impédance mécanique.

C) Moteur synchrone monophasé.

D) Point de vue géométrique. Approximation par le théorème des moments cinétiques.

E) *a*) Alternateur polyphasé. Généralisation au cas du diphasé des équations classiques donnant *p*, *q*, *r*; *b*) moteur synchrone; *c*) généralisation (cas du *n*-phasé); *d*) couplage des machines synchrones; *e*) compoundage des alternateurs; *f*) tableau de corrélation.

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a) Le primaire est le stator. — Fonctionnement en moteur asynchrone. — Fonctionnement en génératrice asynchrone;

b) Le primaire est le rotor.

B) Machines électriques à champ alternatif. Appareils gyroscopiques à vecteur-rotation alternatif.

IV. — *Induction mutuelle entre circuits fixes.*

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VI. — *Générateurs et transformateurs polymorphiques.*

Commutatrice.

VII. — *Réseaux.*

VIII. — *Limites des analogies gyroscopiques.*

IX. — *Applications à la mécanique.*

X. — *Applications à l'énergétique.*

Introduction. — Il y a longtemps que des analogies nombreuses et saisissantes ont été signalées entre la mécanique et l'électricité.

On sait qu'il fut même une époque où des savants espérèrent faire entrer tous les phénomènes dans la mécanique classique, et qu'il s'agirait, au contraire, de nos jours, de rattacher la mécanique et l'électricité à une théorie plus générale.

Nous nous bornerons aujourd'hui à un rôle plus modeste : indiquer des séries d'analogies entre des phénomènes gyroscopiques de nature oscillatoire, et des phénomènes oscillatoires rencontrés en électricité.

Laissant de côté ce problème — d'un haut intérêt, d'ailleurs — la recherche des limites des analogies entre la mécanique classique et l'électricité, nous bornant, en outre, au cas des machines *bipolaires*, nous passerons en revue les principales classes de machines électriques et indiquerons leurs « analogies » dans la mécanique gyroscopique des solides.

Ce sont des analogies mathématiques et non pas seulement de simples ressemblances que nous considérons presque toujours.

On sait le grand parti que Pierre Curie a tiré des considérations de symétrie et de nature des vecteurs.

Le *champ-magnétique* et le *vecteur-rotation* sont des vecteurs de même nature : des *vecteurs-axiaux*. C'est une des bases des analogies gyro-électriques. Nous ferons correspondre à un champ tournant un vecteur-rotation tournant, à un champ alternatif un vecteur-rotation alternatif. Nous combinerons, dans nos appareils gyroscopiques, les vecteurs-rotations comme les électriciens combinent les champs, dans les machines électriques.

D'autre part, et cela aussi est essentiel, nous ferons correspondre le théorème des moments cinétiques à la loi fondamentale de l'induction.

Nous dirons, pour finir, un mot sur la place de ces analogies dans l'*énergétique*, science encore toute jeune dont un chapitre devra englober, avec les machines électriques, diverses autres classes d'appareils et, notamment, les appareils gyroscopiques.

I. — Machines électriques synchrones.

1. *La notion générale d'« excitation » en énergétique et le gyroscope.*

A) La notion d'« excitation » doit être certainement rangée parmi les concepts les plus généraux de l'énergétique.

Laissant, pour aujourd'hui, le côté mathématique de cette question — dont M. Le Corbeiller a mis en lumière certains aspects très intéressants — indiquons quelques réflexions de nature intuitive.

La notion d'« excitation » implique celle d'un phénomène qui peut se poursuivre sans dépense d'énergie et intervenir dans un autre phénomène à peu près à la façon d'un coefficient.

La formule : $C_m = KI\Phi$ qui donne le couple C_m comme proportionnel au flux magnétique Φ montre bien que le flux Φ se trouve en facteur. Or on sait qu'il n'y a, en général, qu'une puissance très faible à dépenser, relativement à la puissance de la machine électrique (dynamo ou alternateur) pour entretenir ce flux Φ.

Considérons un gyroscope, en donnant à ce mot son sens courant : corps de révolution animé d'une vitesse angulaire élevée, soustrait à peu près aux frottements, suspendu à la cardan, et mobile dans tous les sens autour de son centre de gravité.

(Nous serons amenés à généraliser et même à modifier cette définition; mais conservons-la, pour le moment) (*).

Si nous tendons à modifier la direction de son axe, il réagira dans une direction perpendiculaire.

Si, à ce dernier mouvement, s'opposent certaines forces — par exemple, des forces de frottement — il y aura transformation d'énergie.

Dans ce phénomène de transformation, le moment cinétique du gyroscope interviendra comme coefficient, et, en particulier, la vitesse angulaire du gyroscope — qui reste sensiblement inaltérée dans le phénomène.

Cette vitesse angulaire ne correspondrait-elle pas au courant inducteur d'une machine électrique?

C'est ce que nous démontrons plus loin.

2. *L'analogie bien connue du compas magnétique et du compas gyroscopique.*

Maintes fois signalée, elle renforce tout à fait ces considérations intuitives.

3. *La règle de Flemeng ou des trois doigts* (**).

La règle des trois doigts s'applique à la fois au phénomène électrique et au phénomène gyroscopique.

(*) On verra, à propos des appareils asynchrones, les raisons de cette parenthèse.

(**) Voir l'ouvrage de M. Bogaert, *L'effet gyrostatique et ses applications.*

B) ALTERNATEUR MONOPHASÉ. — Nous avons indiqué, dans une note présentée à l'Académie des Sciences de Paris en **1923** (*) qu'un vieil appareil de laboratoire est l'analogue de l'*alternateur électrique monophasé*.

Un anneau A B, suspendu à la cardan, porte un gyroscope entretenu dont l'axe *tt* est perpendiculaire à *bb* (fig. 1).

Grâce à un flexible *f*, on communique au cadre B un mouvement de rotation continue de vitesse angulaire : $\theta' = \omega =$ constante. (On a : $\theta = \omega t$.)

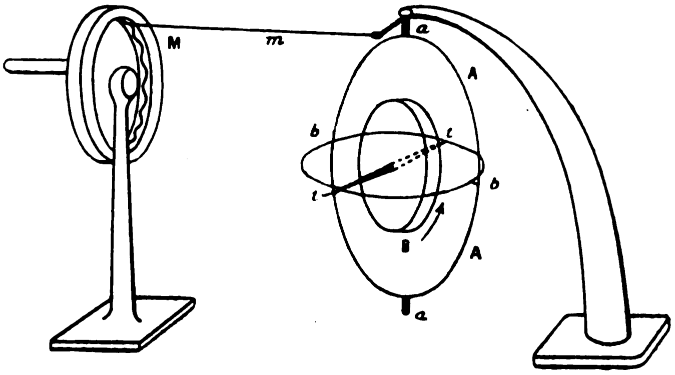

FIG. 1.

Soient, en notations d'Euler, ψ' la vitesse angulaire de l'appareil (alternative, comme on le verra) autour de *aa* et φ' la vitesse de rotation propre du gyroscope.

Dans le cas particulièrement simple où l'ellipsoïde d'inertie du gyroscope est une sphère, nous aurons les équations

$$C_m = A\varphi'\psi' \sin\theta = A\varphi'\psi' \sin\omega t, \qquad (1)$$

qui donne le couple moteur C_m sur l'axe *bb* (A, moment d'inertie du gyroscope).

$$K = (A + P)\psi'' + \frac{d}{dt}(A\varphi' \cos\theta) \qquad (2)$$

où K est le couple extérieur exercé sur l'axe *aa*, et P le moment d'inertie des masses autres que le gyroscope par rapport à *aa* et

$$\varphi' = r_0 - \psi' \cos\theta, \quad \text{avec} \quad r_0 = \text{constante}, \qquad (3)$$

le gyroscope étant abandonné à lui-même et mobile sans frottement dans ses paliers.

Supposons maintenant que le couple extérieur K soit un couple de frottement proportionnel à la vitesse: $K = - R\psi'$, R étant une constante positive.

Faisons, d'autre part, l'approximation : $\varphi' = r_0$, légitime, si l'on admet que la vitesse de rotation du gyroscope soit suffisamment grande vis-à-vis de ψ'.

L'équation (2) qui donne la vitesse ψ' autour de *aa* devient :

$$(A + P)\frac{d\psi'}{dt} + R\psi' = (Ar_0)\,\omega \sin\omega t. \qquad (4)$$

et transpose terme à terme l'équation classique (5):

$$L\frac{di}{dt} + Ri = (\Phi_m)\,\omega \sin\omega t. \qquad (5)$$

La rotation du cadre B porteur du gyroscope, détermine, par suite de ses réactions, un mouvement d'oscillation sinusoïdal du cadre A, que nous supposerons de faible amplitude. La valeur maxima de cette vitesse d'oscillation ψ', qui correspond à l'intensité du courant alternatif débité est :

$$\left.\begin{array}{l} \psi'_{\max} = \dfrac{Ar_0\omega}{\sqrt{(A + P)^2\omega^2 + R^2}} \quad \text{avec} \quad \psi'_{\max} = \omega u_{\max} \\ u_{\max} = \dfrac{1}{2}\,\text{amplitude angulaire.} \end{array}\right\} \qquad (6)$$

L'analogie électrique est évidente et le dénominateur

$$Z = \sqrt{(A + P)^2\omega^2 + R^2}$$

est une « impédance mécanique ».

Plus généralement, à l'impédance électrique, fonction d'une self, d'une pulsation, d'une capacité, d'une résistance ohmique, correspond l'*impédance mécanique*, fonction d'un moment d'inertie, d'une pulsation, d'une élasticité, d'un coefficient de dissipation.

Le couple alternatif d'axe *aa* créant les oscillations de vitesse ψ' est un couple sinusoïdal de

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(*) Sur les analogies gyroscopiques des machines synchrones et asynchrones, et sur la transposition en mécanique de certains diagrammes de l'électrotechnique. (Note de M **BERNARD SALOMON**, présentée par M. **RATEAU**. Séance du 26 février 1923. *C. R.* du 5 mars 1923.)

(*) Quand nous parlons d'amplitude, c'est toujours d'amplitude angulaire qu'il s'agit.

maximum $(Ar_0)\omega$ correspondant à $\Phi_m\omega$, en avance d'un angle λ sur la vitesse ψ', avec

$$\cos\lambda = \frac{R}{\sqrt{(A+P)^2\omega^2+R^2}} \qquad (7)$$

et ce $\cos\lambda$ correspond au $\cos\varphi$ de l'électrotechnique.

La valeur de la puissance de l'« alternateur gyroscopique » est :

$$W = K_{eff} \cdot \psi'_{eff} \cdot \cos\lambda \qquad (8)$$

avec

$$\left.\begin{aligned} K_{eff} &= \frac{\sqrt{2}}{2} K_{max}. \\ \psi'_{eff} &= \frac{\sqrt{2}}{2} \psi'_{max}. \end{aligned}\right\} \qquad (9)$$

Fonctionnement a circuit ouvert :

La résistance ohmique R sera infinie.

Faisons donc : $\psi' = 0$, *en bloquant le cadre A*.

Le couple est nul sur l'axe *bb : il n'y a pas à dépenser d'énergie pour déplacer le gyroscope.*

Autrement dit : *pour une résistance infinie sur l'arbre récepteur* aa, *le moteur se trouve complètement déchargé.*

C'est là une propriété en opposition avec celle des machines courantes.

Fonctionnement en court-circuit :

Soit, au contraire $R = 0$.

Le circuit électrique correspondant, doué de self-induction, et, si l'on veut, de capacité (si l'on ajoute un ressort à l'appareil mécanique), ne comprend pas de résistance ohmique : *le régime est complètement déwatté.* — L'appareil gyroscopique, comme la machine électrique, ne fournit que de la *puissance réactive.*

Le couple moyen est encore nul sur l'arbre moteur *bb*.

Couples et vitesses complexes. — Les couples sinusoïdaux et vitesses sinusoïdales peuvent se représenter par des vecteurs et l'on pourra parler de couples et de vitesses complexes — correspondant aux forces électromotrices et intensités complexes.

C) Moteur synchrone monophasé. — L'appareil est réversible.

Si l'on communique au cadre A la vitesse oscillatoire, de faible amplitude $\psi' = \psi'_{max} \sin \omega t$, le cadre B, *préalablement lancé* autour de l'axe *bb*, dans un sens ou dans l'autre, peut *s'accrocher* sur la vitesse angulaire $\theta' = \omega =$ constante.

L'appareil fonctionne en : « Moteur gyroscopique synchrone monophasé ».

D) Point de vue géométrique. — Faisons l'approximation gyroscopique :

Admettons que la vitesse de rotation propre φ' du gyroscope soit assez grande devant les autres vitesses pour que l'on puisse considérer le moment cinétique du gyroscope comme dirigé suivant son axe et lié à cet axe, condition réalisée, si θ' est faible et si les oscillations ψ' sont de faible amplitude.

Alors, l'axe du gyroscope balaye sensiblement le plan perpendiculaire en O, centre de figure, à la position moyenne de l'axe *bb*, laquelle est perpendiculaire au plan de la figure 2.

Le point M, extrémité du vecteur moment cinétique, décrit un cercle. D'après le théorème des moments cinétiques, *la vitesse de ce point M est, à chaque instant, équipollente au moment résultant des forces extérieures exercées sur le système.* Cela revient à dire que cette vitesse, changée de sens, est, à tout instant, équipollente au couple exercé *par* le gyroscope.

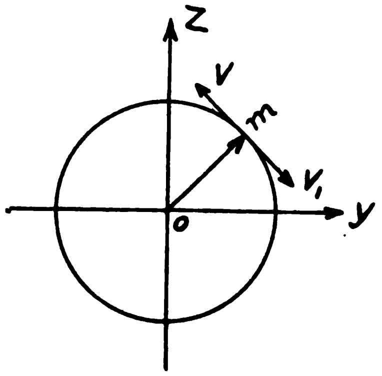


FIG. 2.

En projetant la vitesse mV (fig. 2) sur l'axe OZ axe des ψ', et appliquant ce théorème, on retrouve aisément l'équation (2).

L'alternateur monophasé, décrit précédemment, ne « capte » qu'une des composantes du couple gyroscopique, l'autre déterminant seulement des réactions des appuis.

Il est naturel de capter aussi la composante suivant OY (fig. 2), c'est-à-dire de « diphaser » et, plus généralement, de « polyphaser ».

E) ALTERNATEUR POLYPHASÉ (et moteur synchrone. — *a*) Pour diphaser, enrichissons d'une unité le degré de liberté du système.

L'axe *aa* de la figure 1, au lieu d'être fixe, s'appelle ici *bb* et est porté par un nouveau cadre d'axe perpendiculaire au plan de la figure et susceptible d'osciller autour de cet axe, qui correspond à l'axe Oy de la figure 2.

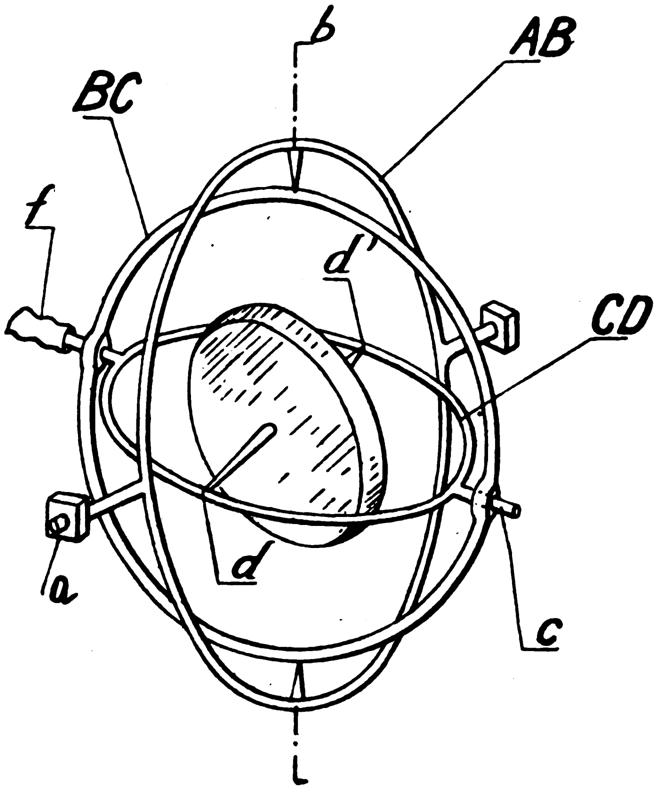


FIG. 3.

Soit α l'angle déterminant, par rapport à la verticale, la position du nouveau cadre, α' la vitesse d'oscillation de ce cadre.

Cette nouvelle vitesse α' jouera un rôle symétrique de celui de ψ' dans les appareils diphasés, synchrones et asynchrones que nous allons voir.

Bien qu'un gyroscope soit déterminé en orientation par *trois* paramètres seulement, il sera commode de le déterminer en « diphasé » à l'aide de *quatre* paramètres: les trois angles θ, φ, ψ d'Euler et ce quatrième angle α.

Autrement dit, comme l'indique la figure 4, on détermine d'abord un trièdre mobile autour de OY ou Oy' par l'angle α, puis le gyroscope, par rapport à Ox_1, y_1, z_1, à l'aide des angles d'Euler — (O X Y Z sont des axes rigoureusement fixes).

GÉNÉRALISATION DES ÉQUATIONS CLASSIQUES DONNANT *p*, *q*, *r*. — La forme généralisée des équations classique :

$$\left.\begin{aligned} p &= \psi' \sin\theta \sin\varphi + \theta' \cos\varphi \\ q &= \psi' \sin\theta \cos\varphi - \theta' \sin\varphi \\ r &= \psi' \cos\theta + \varphi' \end{aligned}\right\} \qquad (10)$$

est ainsi, en diphasé :

$$\left.\begin{aligned} &\left.\begin{aligned} p = {} & \psi' \sin\theta \sin\varphi + \theta' \cos\varphi \\ & + \alpha' [\sin\psi \cos\varphi + \sin\varphi \cos\psi \cos\theta] \end{aligned}\right\} \\ &\left.\begin{aligned} q = {} & \psi' \sin\theta \cos\varphi - \theta' \sin\varphi \\ & + \alpha' [-\sin\psi \sin\varphi + \cos\varphi \cos\psi \cos\theta] \end{aligned}\right\} \\ & r = \varphi' + \psi' \cos\theta - \alpha' \sin\theta \cos\psi \end{aligned}\right\} \qquad (11)$$

où figurent :

$$\left|\begin{array}{l} \psi' \\ \alpha' \;\; \varphi' \;\; \theta' \quad \text{au lieu de} \quad \psi' \;\; \varphi' \;\; \theta' \end{array}\right.$$

Bornons-nous, pour simplifier, au cas de : A = C (gyroscope à ellipsoïde d'inertie sphérique).

Les couples engendrés suivant les axes des ψ' et des α' par le gyroscope, quand on entraîne le cadre CD (fig. 3), porteur du gyroscope, dans une vitesse angulaire $\theta' = \omega =$ constante, sont alors décalés de $\frac{\pi}{2}$ l'un par rapport à l'autre, et,

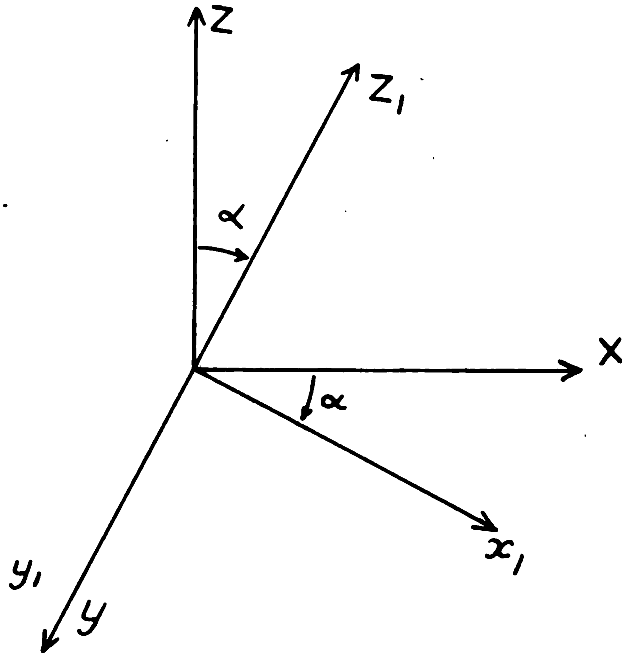


FIG. 4.

si l'on suppose que *tout est symétrique*, les amplitudes d'oscillation pour ψ' et α' et les décalages λ sont les mêmes.

Cela correspond à des *charges égales sur les deux phases de l'alternateur électrique.*

Le régime permanent est déterminé par les équations :

$$\left.\begin{aligned}\psi' &= u'_{\max}\sin(\omega t - \lambda)\\ \alpha' &= u'_{\max}\cos(\omega t - \lambda)\end{aligned}\right\} \qquad (12)$$

où nous supposons $u'_{\max}$ faible
(faible amplitude)

avec :

$$\left.\begin{aligned}u'_{\max} &= \frac{C\rho\omega}{\sqrt{(S - S_1)^2\omega^2 + R^2}}\\ \operatorname{tg}\lambda &= \frac{(S - S_1)\,\omega}{R}\end{aligned}\right\} \qquad (13)$$

et l'on a :

$$\varphi' = r_0 + u'_{\max}\sin\lambda = \rho. \qquad (14)$$

Les quantités S et S_1 représentent certains moments d'inertie fonctions des cadres et du gyroscope.

Le couple moteur vaut algébriquement :

$$C_m = S_1\frac{d}{dt}(\alpha'\psi) + C\varphi'(\psi'\sin\theta + \alpha'\cos\theta). \qquad (15)$$

Dans sa valeur moyenne, seul intervient le second terme et l'on a : couple moteur moyen

$$= C\rho u'_{\max}\cos\lambda. \qquad (16)$$

b) *Moteur synchrone.* — L'appareil est réversible et peut fonctionner en moteur synchrone.

c) *Généralisation.* — (Cas du *n*-phasé.)

Plus généralement, on peut concevoir un système à *n* cadres oscillants.

Remarque : Dans le cas général, nous dirons que les *n* cadres forment une suspension à la Cardan *généralisée* (Suspension ordinaire à la Cardan dans le cas du diphasé).

d) *Couplage des machines synchrones :*

1. *Couplage alternateur-moteur.* — Un appareil gyroscopique marchant en alternateur est conjugué par des bielles, avec un second appareil marchant en moteur synchrone, de façon à réaliser, — en diphasé, par exemple :

$$\psi'\,(\text{alternateur}) = \psi'\,(\text{moteur})$$
$$\alpha'\,(\text{alternateur}) = \alpha'\,(\text{moteur}).$$

L'électrotechnique suggère alors, entre autres problèmes, les suivants :

Mise en marche, accrochage. Fonctionnement en marche normale. Marche d'un moteur synchrone à puissance et excitation données. Maximum de stabilité. Détermination des amplitudes maxima d'oscillation. Marche du moteur à puissance constante et excitation variable, etc., etc.

Les solutions sont à peu près évidentes, et l'on peut, en particulier, transposer les théories de M. Blondel.

2. *Couplage en parallèle des alternateurs.* — Voici la transposition gyroscopique pour le cas du « monophasé ».

Les alternateurs gyroscopiques A_1 et A_2 font osciller les planétaires B_1 et B_2 en prise avec les satellites S_1 et S_2 portés par la coquille d'un différentiel, coquille qui entraîne un pignon D, en prise avec un pignon E de diamètre moitié.

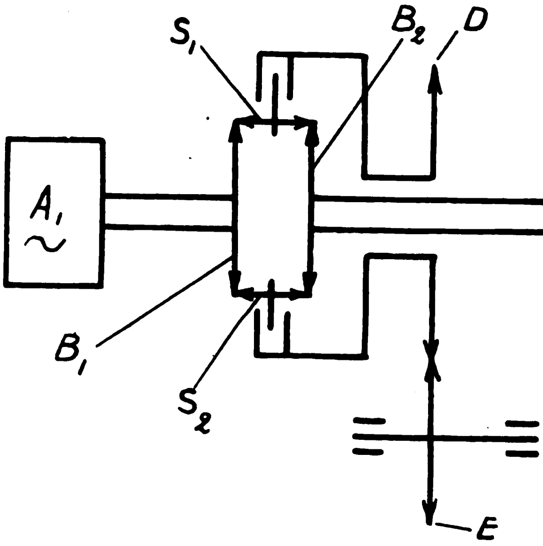


Fig. 5.

Si ψ'_1 et ψ'_2 sont les vitesses d'oscillation instantanées des pignons B_1 B_2 correspondant aux ψ' des deux alternateurs, la vitesse d'oscillation de D est, pour des sens bien choisis : $-\frac{\psi'_1 + \psi'_2}{2}$ et celle de E : $\psi'_1 + \psi'_2$.

Le pignon E, doué d'inertie (self-induction) est soumis à l'action d'un couple de frottement proportionnel à sa vitesse angulaire, ce qui transpose les pertes joule.

En outre, il est soumis à l'action d'un ressort, ce qui correspond aux phénomènes de capacité.

Les problèmes de mécanique corrélatifs à ceux de l'électrotechnique et qui se posent alors tout naturellement sont très nombreux.

Indiquons (*): — Mise en parallèle. — Stabilité de la marche en parallèle. — Oscillations de deux alternateurs couplés. — Influence des oscillations sur les couples alternatifs exercés sur les cadres, etc., etc.

e) *Compoundage des alternateurs.* — Si l'on envisage les couples alternatifs engendrant les oscillations ψ' et α', on peut chercher à les maintenir constants, quelles que soient ces vitesses ψ' et α' et les circonstances extérieures : c'est le problème du compoundage.

f) *Tableau de corrélation.* — Nous résumerons les analogies rencontrées, dans le tableau suivant :

Vitesse de rotation θ' de l'arbre du flexible. → Vitesse de l'arbre de la machine électrique.
Cadres extérieurs oscillants formant suspension à la cardan simple ou généralisée. → Stator.
Gyroscope et son cadre support. → Rotor.
Nombre de cadres extérieurs oscillants. → Nombre de phases du stator.
Vecteurs-rotations. → Champs.
Moments cinétiques. → Flux.
Vitesse de rotation propre du gyroscope. → Courant inducteur.
Vitesses d'oscillation des cadres extérieurs. → Intensités statoriques.
Couples créant ces oscillations. → Forces électromotrices induites dans le stator.
Décalages entre les couples et les vitesses. → Décalages entre les forces électromotrices induites et les intensités débitées.
Impédances mécaniques. → Impédances électriques.
Fonctionnement à oscillations bloquées. → Fonctionnement à circuit ouvert.
Fonctionnement sans équipage extérieur et sans fonction de dissipation. → Fonctionnement en court-circuit.

II. — Les analogies mécaniques de l'électricité et le problème du changement de vitesse progressif.

Les analogies signalées entre la mécanique et l'électricité, et, plus particulièrement, entre les phénomènes gyroscopiques et les machines électriques, suggèrent l'existence d'une corrélation entre certains problèmes posés par l'électrotechnique et le problème du changement de vitesse progressif.

Nous n'entrerons pas, pour aujourd'hui, dans le détail de cette question, qui nous entraînerait très loin.

Nous nous bornerons à indiquer que cette corrélation existe et qu'elle est même très étroite.

Nous décrirons aussi, comme application de l'alternateur gyroscopique polyphasé, un appareil de transmission gyroscopique que nous avons étudié et dont une maquette se trouve à Paris, dans le Laboratoire de Mécanique de l'École Polytechnique (*).

a) *Description d'un appareil de transmission gyroscopique.* — Les figures 7 et 8 donnent sa vue en élévation et en plan. La figure 6 montre la suspension à la Cardan des cadres et reproduit la figure 2.

L'appareil comprend :

1. Un générateur d'oscillations transformant le mouvement circulaire de l'arbre moteur (qui entraîne le flexible) en mouvements d'oscillation diphasés autour de deux axes rectangulaires.

2. Un récepteur constitué par un arbre per-

(*) D'après M. Janet (t. III).

(*) L'Administration française des Postes et Télégraphes a exposé cet appareil dans son stand, à la Foire de Paris, en 1928. Il portait l'inscription suivante : « Transmission gyroscopique; système Bernard Salomon. Construit en 1924 par la Société *La Précision Moderne*. Prêté par l'École Polytechnique. »

pendiculaire à l'axe de l'arbre moteur et sur lequel sont disposées quatre roues libres.

Des bielles relient le générateur au récepteur et communiquent les mouvements d'oscillation aux roues libres qui les redressent. L'arbre récepteur qui reçoit, par tour de l'arbre moteur, quatre impulsions sélectionnées et également réparties dans le temps, prend un mouvement circulaire continu. Il porte un volant.

L'amplitude $2u_{\max}$ *des oscillations est cinématiquement libre.* Elle dépend d'éléments dynamiques, comme l'excitation du gyroscope, les moments d'inertie des pièces en mouvement, le couple résistant sur l'arbre récepteur, pour une vitesse angulaire donnée ω de l'arbre moteur.

La formule déjà donnée :

$$u'_{\max} = \frac{C\rho\omega}{\sqrt{(S - S_1)^2\omega^2 + R^2}} \quad \text{avec} \quad u'_{\max} = \omega u_{\max} \qquad (13)$$

$u_{\max}$ étant la demi-amplitude angulaire, s'applique sensiblement, moyennant certaines hypothèses.

Les roues libres communiquent sensiblement à l'arbre récepteur une vitesse angulaire égale à leur vitesse maxima positive, elle-même proportionnelle à la vitesse maxima $u'_{\max}$ des oscillations ψ' et α' (qui est la même pour ψ' et pour α') et qui est proportionnelle à l'amplitude $2u_{\max}$.

On voit donc que l'appareil est une *transmission progressive*, puisque $u'_{\max}$ est susceptible de variation progressive, notamment, si l'on fait varier la vitesse de rotation propre du gyroscope, c'est-à-dire, *si l'on fait varier l'excitation de l'alternateur gyroscopique.*

b) *Propriétés essentielles :*

1. *Embrayage.* — Il y a *désembrayage,* si l'excitation est nulle.

Si elle augmente, l'embrayage a lieu progressivement, *pourvu toutefois que la vitesse de l'arbre moteur soit suffisante.*

L'appareil ne joue donc pas seulement le rôle d'embrayage, mais celui *d'embrayage automatique.*

2. *Changement de vitesse progressif.* — C'est aussi un changement de vitesse progressif. Cela résulte de ce qui a été dit et de la formule (13).

3. *Changement de vitesse automatique.* — L'excitation du gyroscope (sa vitesse de rotation propre), peut être commandée soit *volontairement,* soit *automatiquement,* de façon à réaliser telle condition déterminée, et, notamment, la constance de la vitesse ω de l'arbre moteur quand le couple résistant varie; le rapport de transmission est alors réglé automatiquement de façon à établir l'équilibre des puissances motrice et réceptrice, pour un régime constant du moteur.

Pour ce résultat, la vitesse de rotation propre du gyroscope doit, sous certaines conditions simples, avoir la valeur :

$$\varphi' = \frac{1}{C}\sqrt{\frac{C_m^2}{p^2\omega_1^2} + L^2p^2\omega_1^2} \qquad (16)$$

dans laquelle C est, comme précédemment, le moment d'inertie du gyroscope par rapport à son axe, C_m le couple moteur maintenu constant, ω_1 la vitesse angulaire variable de l'arbre récepteur, L un certain moment d'inertie, p une certaine constante de l'appareil.

4. *Cas du blocage de l'arbre récepteur.* — D'après ce qui a été dit, pour l'alternateur gyroscopique, *si l'on bloque l'arbre récepteur, on décharge complètement le moteur.*

En effet, les oscillations des cadres du stator deviennent nulles et le couple moteur C_m ne trouve plus aucun *couple antagoniste pour* l'équilibrer, car on a :

$$C_m = (C\rho)\, u'_{\max} \cos\lambda \quad (\text{et } u'_{\max} = 0). \qquad (16')$$

(Cela correspond, on l'a vu, au cas électrique du circuit ouvert.)

Cette propriété qui pourrait être précieuse, notamment pour la protection d'un moteur électrique, *différencie absolument cette transmission des transmissions à liaisons complètes,* dans lesquelles l'arbre moteur est évidemment bloqué, si l'arbre récepteur est bloqué.

5. *Rendement de la transmission.* — L'excitation du gyroscope ne demande qu'une puissance minime (1 % à peine de la puissance transmise).

Cette excitation se fait, d'ailleurs, sans aucune espèce de difficulté par l'air comprimé, ou électriquement, ou par friction. (Il n'est pas du tout nécessaire que le gyroscope tourne très vite.)

Le rendement ne dépend pratiquement que de celui des roues libres.

Il est inutile d'ajouter que les formes représentées, notamment à cause du flexible et des effets d'inertie sur les cadres, ne concernent pas un type industriel.

6. *Dynamomètre de transmission.* — La formule (16) montre que tout est connu — et, notamment, le couple moteur — si les vitesses mises en jeu sont connues.

C'est encore un résultat essentiellement distinct de ceux que donnent les transmissions ordinaires.

L'appareil peut donc jouer le rôle de *dynamomètre de transmission.*

7. *Analogies électriques.* — L'ensemble correspond au groupement électrique : alternateur diphasé — redresseur (*). Le redresseur débite quatre fois pendant un tour de l'arbre moteur, c'est-à-dire pendant une période.

En électricité, on obtient par un montage approprié ce même résultat, ici obtenu grâce à la disposition des bielles.

Le volant monté sur l'arbre récepteur correspond à une self en série sur le circuit du courant redressé.

(*) Les roues libres correspondent *en gros* à un redresseur. Il semble qu'il y ait là plus une *ressemblance* qu'une véritable *analogie*, au sens bien déterminé où nous employons ce mot.

Fig. 6

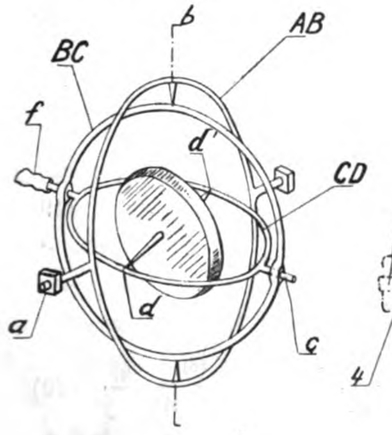


Fig. 7

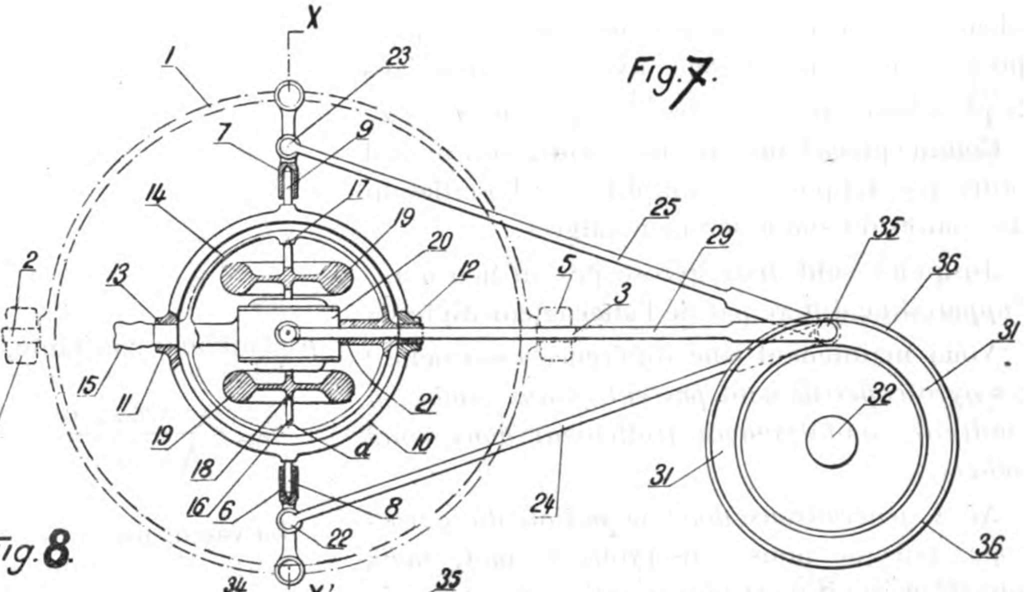


Fig. 8

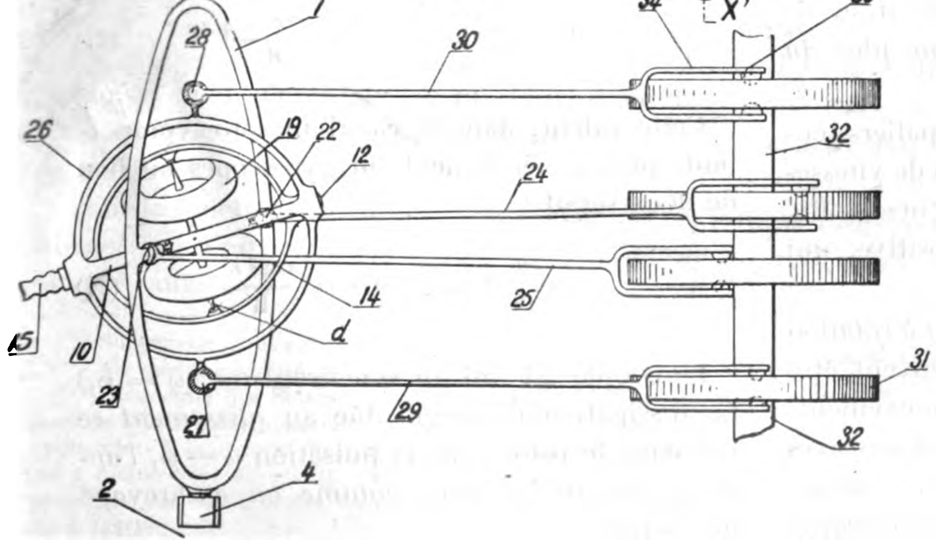
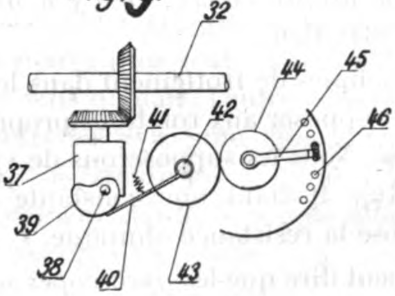


Fig. 9



A noter qu'à la nécessité électrique du *redresseur* pour avoir du courant continu correspond, dans cette transmission, la nécessité des *roues libres* (ou encliquetages).

III. — Machines asynchrones.
Généralisation de la notion de gyroscope.
Gyroscopes à φ' alternatif.

A) *Machines électriques à champ tournant.*

Il leur correspond les appareils gyroscopiques *à vecteur-rotation tournant.*

a) *Le primaire est le stator.*

1. *Fonctionnement en moteur.* — Reprenons l'appareil diphasé des figures 6, 7 et 8, mais modifié de la manière suivante : le rotor, au lieu de porter un seul gyroscope, en porte deux, identiques, d'axes perpendiculaires. Dans la position moyenne, ces deux axes se trouvent dans le plan formé par l'axe des ψ' et par celui des α'.

Comme précédemment, les quantités du second ordre par rapport aux amplitudes d'oscillation des cadres du stator seront négligées.

Jusqu'ici, sauf *deux* gyroscopes au lieu *d'un, l'appareil* ne diffère pas de l'alternateur diphasé.

Voici maintenant une différence essentielle : *les gyroscopes ne sont pas entretenus, mais, au contraire, mobiles avec frottement dans leurs paliers.*

Nous généralisons donc la notion du gyroscope, puisque nous conservons le mot, *mais admettons qu'il n'est plus question de vitesse de rotation propre élevée. Il n'y a même plus du tout d'entretien.*

Les couples de frottement dans les paliers tendent à s'opposer aux rotations propres de vitesses φ'_1 et φ'_2. Nous les supposerons de valeurs $-R\varphi'_1$ et $-R\varphi'_2$, R étant une constante positive, qui transpose la résistance ohmique.

On peut dire que les *gyroscopes sont à rotation propre freinée* et l'on voit qu'ils peuvent être *entraînés par adhérence* dans les mouvements de rotation ou d'oscillation par rapport aux axes fixes, si leurs paliers reçoivent de tels mouvements. *Nous pourrons donc avoir des gyroscopes à mouvements alternatifs.* Les mouvements alternatifs des gyroscopes peuvent s'obtenir autrement que par adhérence dans leurs paliers.

Alimentons le stator — autrement dit, communiquons aux cadres extérieurs des mouvements d'oscillation de faible amplitude, de vitesses :

$$\psi' = u'_{\max} \sin \omega t \qquad \alpha' = u'_{\max} \cos \omega t \tag{17}$$

L'appareil peut démarrer de lui-même : le système porteur des gyroscopes (rotor) prend, une fois le régime permanent établi, une vitesse de rotation :

$$\theta' = \omega_1 = \text{constante} \quad \text{avec } \omega_1 < \omega.$$

Les équations de Lagrange appliquées aux gyroscopes donnent :

$$\left.\begin{aligned} -R\varphi'_1 &= C\varphi''_1 + \frac{d}{dt} C(\psi' \cos\theta - \alpha' \sin\theta) \\ -R\varphi'_2 &= C\varphi''_2 - \frac{d}{dt} C(\psi' \sin\theta + \alpha' \cos\theta) \end{aligned}\right\} \tag{18}$$

et l'on a :

$$\left.\begin{aligned} \varphi'_1 &= -\varphi'_{\max} \cos[(\omega - \omega_1)t - p - \lambda] \\ \varphi'_2 &= -\varphi'_{\max} \sin[(\omega - \omega_1)t - p - \lambda] \end{aligned}\right\} \tag{19}$$

p étant une constante,

$$\varphi'_{\max} = \frac{(Cu'_{\max})(\omega - \omega_1)}{\sqrt{C^2(\omega - \omega_1)^2 + R^2}}, \quad \operatorname{tg} \lambda = \frac{C(\omega - \omega_1)}{R}. \tag{20}$$

La valeur du couple moteur est :

$$C_m = (Cu'_{\max})^2 (\omega - \omega_1) \frac{\cos^2 \lambda}{R}. \tag{21}$$

Cette valeur, dans le cas d'un rotor comportant, plus généralement, *m* gyroscopes au lieu de deux serait :

$$C_m = \frac{m}{2} (Cu'_{\max})^2 (\omega - \omega_1) \frac{\cos^2 \lambda}{R}. \tag{22}$$

Le couple est nul au synchronisme $(\omega = \omega_1)$ La dissipation d'énergie dûe au *glissement* se fait dans le rotor sous la pulsation $\omega - \omega_1$ *l'appareil fonctionne donc comme un embrayage qui patine.*

Les analogies électriques se résument dans le tableau suivant :

Comme dans le moteur synchrone.	Suspension (*) formée par les cadres extérieurs.	→	Stator.
	Nombre d'axes d'oscillation de ces cadres.	→	Nombre de phases du stator.
	Vitesses d'oscillation de ces cadres.	→	Intensités statoriques.
	Système porteur des gyroscopes (**).	→	Rotor.
	Vitesses de rotation propre des gyroscopes.	→	Intensités rotoriques.
	Nombre de gyroscopes.	→	Nombre de bobines du rotor.
	Vecteur-rotation tournant $u'_{\max}$.	→	Champ tournant.
	Moment cinétique $Cu'_{\max}$.	→	Flux inducteur.
	Coefficient R.	→	Résistance ohmique d'une bobine du rotor.
	Décalage λ.	→	Décalage rotorique de self-induction.

Au point de vue mécanique, l'appareil est un moteur gyroscopique asynchrone polyphasé transformant en mouvement circulaire continu de vitesse variable ω_1 des mouvements d'oscillation polyphasés de pulsation ω et d'amplitude variable.

2. *Fonctionnement en génératrice asynchrone.* — Le système précédent est réversible et peut fonctionner en « *générateur asynchrone d'oscillations* ».

Cela signifie que, le rotor étant entraîné par un moteur, on peut recueillir, sur les cadres du stator, des mouvements d'oscillation dont la pulsation sera différente de celle qui correspond à la vitesse angulaire du moteur et dans un rapport graduellement variable avec elle — avec transfert d'énergie.

C'est la transposition mécanique du système de génératrice asynchrone indiqué par Maurice Leblanc.

Electriquement, la pulsation doit être donnée par un « chef d'orchestre » qui fournit de la puissance réactive, et mécaniquement, il en est de même.

Pour le fonctionnement *au-dessus du synchronisme*, qui n'est d'ailleurs pas le seul cas possible, on aura $\omega_1 > \omega$ (***). Le glissement — ici négatif — s'accompagne, bien entendu, d'une dissipation d'énergie dans le rotor.

b) Le primaire est le rotor.

On peut se donner, grâce à des liaisons appropriées :

$$\varphi'_1 = u'_{\max} \sin \omega t \qquad \varphi'_2 = u'_{\max} \cos \omega t \tag{23}$$

c'est-à-dire alimenter le rotor. Les propriétés sont analogues.

B) *Machines à champ alternatif.*

Il leur correspond des appareils gyroscopiques à « vecteur-rotation » alternatif.

L'appareil de la figure 10 ne diffère de l'appareil asynchrone diphasé que par un degré de liberté de moins.

$$\alpha' = 0, \qquad \alpha = 0.$$

Le cadre des α' est fixe et le stator est monophasé.

Le rotor, diphasé, est identique au précédent.

Le rotor ne démarre plus seul : lancé préalablement dans un sens ou dans l'autre, son mouvement peut continuer avec une vitesse angulaire uniforme ω_1 inférieure à ω.

Le régime permanent établi, le couple moteur vaut (pour *m* gyroscopes au rotor)

$$C_m = \frac{m}{8}\,\frac{(Cu'_{\max})^2\,R\,(\omega - \omega_1)}{R^2 + C^2\,(\omega - \omega_1)^2} - \frac{m}{8}\,\frac{(Cu'_{\max})^2\,R\,(\omega + \omega_1)}{R^2 + C^2\,(\omega + \omega_1)^2}. \tag{24}$$

Il est la différence de deux couples égaux lors du repos.

En même temps, les vitesses de rotation pro-

(*) Suspension à la cardan simple ou généralisée.

(**) Au sens généralisé de ce mot « gyroscope ».

(***) Académie des Sciences. Sur les analogies gyroscopiques de l'électricité, appareils gyroscopiques asynchrones et application à la théorie du gyroscope à mouvement continu ou à mouvement alternatif. (Note de M. Bernard Salomon, présentée par M. Mesnager. Séance du 30 janvier 1928. *C. R.* du 6 février 1928.

pre des gyroscopes sont la superposition de vitesses des deux pulsations $\omega + \omega_1$ et $\omega - \omega_1$.

La théorie est parallèle à la théorie électrique et les corrélations sont les mêmes que précédemment.

L'appareil est un moteur gyroscopique asynchrone monophasé transformant en mouvement de rotation continu de vitesse angulaire ω_1 inférieure à ω un mouvement d'oscillation de pulsation ω, et transpose le moteur monophasé d'induction.

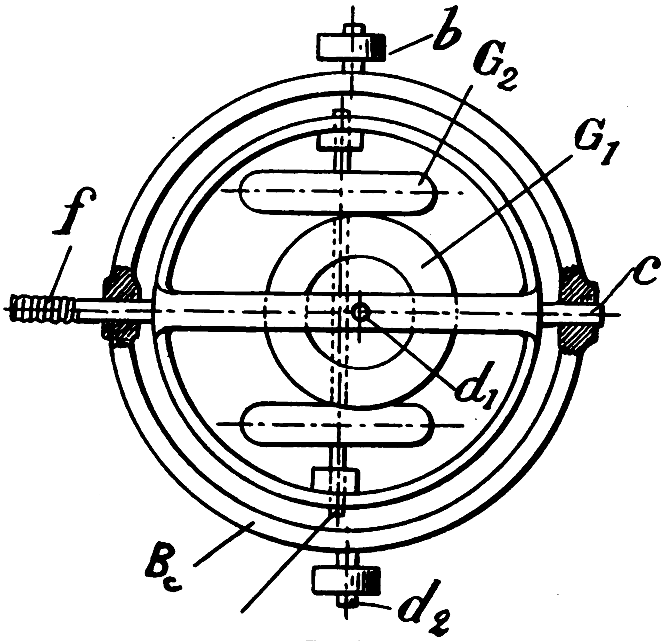


FIG. 10.

IV. — Induction mutuelle entre circuits fixes.

Le transformateur.

a) Description et propriétés. — Si l'on bloque le rotor dans un appareil asynchrone, on doit trouver l'analogie de l'induction mutuelle entre circuits fixes et transposer une forme de transformateur.

C'est ce qu'un calcul simple vérifie.

Prenons le cas d'un seul gyroscope au rotor, et soit $\theta = \theta_0$ l'angle fixe que fait son axe avec l'axe des ψ'.

Sur l'équipage ψ' un couple alternatif K est appliqué, en même temps qu'un couple de freinage proportionnel à la vitesse, c'est-à-dire de la forme $-R_1\psi'$ $(R_1 > 0)$. Comme précédemment, un couple de la forme $-R\varphi' (R > 0)$ est appliqué aux oscillations du gyroscope dans ses paliers.

Les équations de Lagrange s'écrivent :

$$\left.\begin{aligned} K &= R_1\psi' + (A\sin^2\theta_0 + C\cos^2\theta_0)\frac{d}{dt}(\psi') \\ &\qquad + C\cos\theta_0\frac{d}{dt}(\varphi') \\ 0 &= R\varphi' + C\frac{d}{dt}(\varphi') + C\cos\theta_0\frac{d}{dt}(\psi') \end{aligned}\right\} \quad (25)$$

et correspondent terme à terme aux équations bien connues

$$\left.\begin{aligned} u_1 &= R_1 i_1 + L_1\frac{di_1}{dt} + M\frac{di_2}{dt} \\ 0 &= R_2 i_2 + L_2\frac{di_2}{dt} + M\frac{di_1}{dt}. \end{aligned}\right\} \quad (26)$$

Le couple K correspond à la force électromotrice alternative u_1, les vitesses ψ' et φ' aux courants i_1 et i_2, les moments d'inertie $(A\sin^2\theta_0 + C\cos^2\theta_0)$ et C à L_1 et L_2. Enfin, la quantité $C\cos\theta_0$ au coefficient d'induction mutuelle M.

V. — Machines à courant continu.

Comme pour les autres machines, nous ne considérons que le cas du *bipolaire*.

Nous transposerons les machines à collecteur fixe et inducteurs (et balais) mobiles.

a) Génératrice. — Modifions l'alternateur des figures 2, 7, 8.

Nous allons lui adjoindre des encliquetages, mais nous leur ferons jouer un rôle différent de celui que jouent les encliquetages de la « transmission gyroscopique ». (Fig. 7, 8.)

Ces derniers encliquetages ne sont pas « commandés »; ils agissent à l'instant où la vitesse angulaire à capter passe par un maximum, et nous avons indiqué qu'on peut — en gros — faire correspondre ces encliquetages aux redresseurs de courant.

Au contraire, les encliquetages à considérer dans la transposition du collecteur sont des encliquetages *commandés*.

Chaque cadre extérieur (celui des ψ', celui des α' etc.) est conjugué avec une roue à rochet qui a la même vitesse angulaire que lui.

Des roues à cliquets sont montées concentriquement aux roues à rochet.

Il y a $2n$ cadres extérieurs régulièrement disposés (stator $2n$-phasé).

A un instant initial, les roues à rochet **1**, **2**, **3**, ... n correspondant aux cadres de même nom sont solidarisés par des cliquets avec un arbre A, ce qui oblige tous ces cadres à tourner à la vitesse angulaire $+\omega$.

Les cadres $n+1$, $n+2$ ... $2n'$, sont alors, de même par rochets et cliquets, solidarisés avec un arbre qui tourne à la vitesse angulaire $-\omega$.

A mesure que tourne l'arbre des θ' (porteur du gyroscope excité) les divers cliquets sont successivement commandés par des cames, au moment précis où l'axe du gyroscope fait un angle λ avec l'axe du cadre correspondant.

C'est ainsi que, à un second instant, on a :

VITESSE ANGULAIRE ω.	VITESSE ANGULAIRE $-\omega$.
Cadres 2	Cadres $n+2$
3	$n+3$
$\vdots$	$\vdots$
n	$2n$
$n+1$	1

et les permutations circulaires continuent indéfiniment.

La vitesse angulaire W de l'arbre A, qui reçoit la somme des impulsions communiquées par le gyroscope aux n-cadres qui lui sont conjugués à un instant, correspond à l'intensité du courant $+$ I débité.

La vitesse angulaire $-$ W correspond au courant $-$ I qui rentre dans le dynamo.

La vitesse angulaire de chaque cadre passe brusquement de $+$ W à $-$ W, quand sa roue à rochet est lâchée par les cliquets de l'arbre A pour être saisie par les cliquets de l'arbre B. Cette variation brusque correspond à la *commutation*.

A la formule :

$$E = K\omega(n)\Phi \text{ (*)} \qquad (27)$$

de l'électrotechnique, correspond pour le couple S, à la sortie de l'appareil gyroscopique, la formule :

$$S = K'\omega(2n)\mathfrak{M} \qquad (28)$$

K et K′ étant des constantes, $\theta' = \omega$ la vitesse angulaire du cadre portant le gyroscope (vitesse du rotor).

$\mathfrak{M}$ est le moment cinétique utile.

b) *Moteur.* — L'appareil décrit est évidemment réversible. Si les arbres A et B reçoivent des vitesses angulaires $+W$ et $-W$, le rotor prend une certaine vitesse angulaire θ^1, dans un rapport graduellement variable avec W_1.

Ce rapport dépend, d'ailleurs, des diverses forces en jeu, de l'excitation du gyroscope, etc.

REMARQUES. — L'appareil, dans le fonctionnement en génératrice comme dans le fonctionnement en moteur, constitue une *transmission gyroscopique à vitesse graduellement variable*.

Ainsi, des *encliquetages commandés* correspondent au *collecteur*.

VI. — Générateurs et transformateurs polymorphiques.

Les indications succinctes données précédemment font entrevoir que les généralisations possibles sont extrêmement larges et qu'on peut espérer retrouver, dans le domaine gyroscopique, des corrélations extrêmement variées du domaine électrique.

Bornons-nous à un exemple :

Commutatrice. — Elle participe de la dynamo à courant continu et de l'alternateur.

Gyroscopiquement, on combinera les deux types que nous avons indiqués.

VII. — Réseaux.

Nous dirons deux mots seulement.

On a transposé — à propos du couplage des alternateurs — la *dérivation*. L'analogie du montage en série étant, d'autre part, évidente (nous avons, d'ailleurs, eu l'occasion de la voir, en transposant la dynamo), on voit qu'il est aisé de transposer tout réseau éectrique.

On retrouve aisément — ce qui est bien connu — que les équations de Kirchoff correspondent aux équations de Lagrange.

Ces remarques conduisent à des développements très larges.

VIII. — Limites des analogies gyroscopiques.

Nous avons dit, dès le début, que nous n'aborderions pas ce sujet, pour aujourd'hui. Il nous semble d'ailleurs que son intérêt scientifique et philosophique soit considérable.

(*) $2n$ est, si l'on veut, le nombre de spires d'un anneau gramme.

IX. — Applications à la mécanique.

Nous espérons avoir montré que les analogies électriques projettent sur la théorie du gyroscope une lumière éclatante, qu'il s'agisse du *gyroscope*, selon la définition classique, c'est-à-dire, si l'on veut, du *gyroscope à* φ' *continu*, ou qu'il s'agisse de problèmes, jusqu'ici laissés dans l'ombre, croyons-nous, et concernant le gyroscope à φ' *alternatif*.

Les illustrations que nous avons données, notamment dans le domaine synchrone et dans le domaine asynchrone, seront peut-être jugées convaincantes.

Nous avons d'ailleurs fait entrevoir la multitude des problèmes tout posés et tout enchaînés et, souvent, tout résolus que suggère l'électrotechnique.

X. — Applications à l'énergétique.

Dans cette science si jeune qu'est l'Energétique, le livre des machines doit comprendre un chapitre englobant, dans une théorie générale, avec les machines électriques, divers appareils mécaniques et, notamment, les appareils gyroscopiques que nous avons décrits.

Parmi les notions fondamentales, figurera celle d'*énergie réactive*, particulièrement mise en lumière, dans le domaine électrique par M. Boucherot, et dont l'importance doit être étendue, semble-t-il, à tout le domaine énergétique.

Après l'exposé des communications scientifiques, M. le Prof^{r} Vanni ajoute qu'il lui reste à remplir une tâche très flatteuse qui lui a été confiée par l'Association Electrotechnique Italienne: c'est la présentation au Président de cette Union du volume contenant les travaux présentés à Côme en octobre 1927, à l'occasion des cérémonies en l'honneur de Volta. Dans une circonstance analogue, lors du cinquantenaire de professorat de Lord Kelvin, la même Association voulut rendre hommage à l'illustre savant anglais, en lui présentant un exemplaire du « Code Atlantique », de Léonard de Vinci; l'ensemble des travaux mathématiques, d'hydraulique et d'aérodynamique du grand artiste et savant de la Renaissance italienne fut considéré comme le moyen le plus convenable pour honorer la science anglaise. Maintenant, la patrie de Volta, de Galvani, de Galileo Ferraris, de Marconi saisit l'occasion pour rendre hommage à l'Union Radio Scientifique Internationale qui comprend les savants et les techniciens du monde entier.

Le Président de l'Union, M. le Général Ferrié, remercie vivement le Prof^{r} Vanni, en le priant de vouloir bien se rendre interprète des sentiments de l'Assemblée auprès de l'Association Electrotechnique Italienne.

Bruxelles. — Imp. Hayez, rue de Louvain, 112.

Mai
Mey 1929 VOL. II Fascicule 2

Union Radio Scientifique Internationale

International Scientific Radio Union

PALAIS DES ACADÉMIES, BRUXELLES

Secrétariat Général : 54, avenue des Arts, Bruxelles

Recueil des Travaux de l'Assemblée Générale tenue à Bruxelles en Septembre 1928
Papers of the General Assembly held in Brussels in September 1928

COMPTES RENDUS DE L'ASSEMBLÉE GÉNÉRALE
(Textes originaux)

MINUTES OF THE GENERAL SESSION
(Original texts)

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INTRODUCTION

L'Assemblée Générale de l'U. R. S. I., tenue à Bruxelles en septembre 1928, comportait, outre l'Assemblée Générale proprement dite, des séances des cinq Commissions de l'U. R. S. I. et une séance publique.

Le programme des séances fut établi comme suit :

Lundi 10 septembre : Séance inaugurale.
Mercredi 12 septembre : Séances des Commissions.
Jeudi 13 septembre : Séance publique.
Vendredi 14 septembre : Séances des Commissions.
Samedi 15 septembre : Séance générale.

Les séances générales ainsi que la séance publique furent présidées par M. le Général Ferrié, Président de l'U. R. S. I.

Les délégués officiels des pays adhérents à l'U. R. S. I. étaient les suivants :

Belgique : MM. l'Ingénieur R. CORTEIL, le Profr TH. DE DONDER, le Profr R. B. GOLDSCHMIDT, l'Ingénieur P. GOLDSCHMIDT, le Profr CH. MANNEBACK, le Profr PHILIPPSON et le Colonel WIBIER.

États-Unis d'Amérique : MM. le Dr L. W. AUSTIN, le Dr L. M. HULL, l'Ingénieur JENSEN, le Profr A. E. KENNELLY, le Dr T. PARKINSON et l'Ingénieur N. SNYDER.

France : MM. le Général FERRIÉ, l'Ingénieur P. BRENOT, le Capitaine BUREAU, l'Ingénieur LE CORBEILLIER, le Profr MESNY et l'Ingénieur SALOMON.

Grande-Bretagne : MM. le Profr E. V. APPLETON, O. F. BROWN, le Dr D. DYE, le Dr SMITH-ROSE, le Dr E. H. RAYNER, le Dr R. A. WATSON-WATT.

Italie : M. le Profr G. VANNI.

Japon : M. le Profr H. NAGAOKA.

Pays-Bas : MM. J. A. BLAND VAN DER BERG; le Dr C. L. VAN DER BILT et le Dr BALTH. VAN DER POL.

Union Sud-Africaine : M. l'Ingénieur C. W. R. CAMPBELL.

Le *Secrétariat général* était composé de MM. le Dr R. B. GOLDSCHMIDT, Secrétaire général, l'Ingénieur P. GOLDSCHMIDT, Secrétaire général-adjoint, et le Dr HOMES, attaché technique.

Outre ces personnalités assistaient à l'Assemblée :

MM. l'Ingénieur BRAILLARD, le Profr DACOS, l'Ingénieur DE BURLET, le Profr JANNE, le Profr MOENS, le Profr VAN DEN DUNGEN, ainsi qu'en qualité d'assistants : MM. DE VAUCLEROY, le Capitaine HERBAYS et l'Ingénieur REVOL.

Séance Inaugurale du 10 Septembre 1928

Opening Session, September 10, 1928

M. le Profr De Donder, Président du Comité National Belge de l'U. R. S. I., prononce l'allocution suivante :

Messieurs,

Le Comité Belge de Radiotélégraphie Scientifique a été très flatté d'apprendre que l'U. R. S. I. avait en principe choisi Bruxelles comme siège du Secrétariat Général et de la présente Assemblée Générale.

Au nom de ce Comité, j'adresse à Messieurs les Délégués étrangers qui nous ont fait l'honneur de répondre à l'appel qui leur fut adressé, nos meilleurs souhaits de bienvenue, et je les remercie vivement de l'éminente collaboration qu'il nous apportent.

Ce concours est pour le Comité Belge le plus précieux des encouragements. Je puis vous assurer que notre Comité s'efforcera d'apporter, à son tour, une collaboration efficace aux travaux de l'Union. Ce sera pour le Comité Belge une tâche bien agréable de mettre tout en œuvre pour que vous conserviez le meilleur souvenir de la Belgique.

Messieurs,

Je suis convaincu qu'en prononçant ce mot de « Belgique » toutes vos pensées se portent vers son Chef vénéré. Qu'il me soit permis aussi de rappeler que le Roi des Belges a bien voulu accepter la Présidence d'Honneur de la Commission de Télégraphie Sans Fil Scientifique (T. S. F. S.), dont la présente Union est issue.

Aussi, j'ai l'honneur de vous proposer d'envoyer le télégramme suivant au Roi :

Les Délégués de l'Union Internationale de Radiotélégraphie Scientifique, réunis en Assemblée Générale au Palais des Académies, prient Sa Majesté le Roi des Belges d'agréer leurs sentiments de respectueuse admiration.

Ils se rappellent avec la plus profonde gratitude que Sa Majesté accepta la Présidence d'Honneur de la Commission Internationale de Télégraphie Sans Fil Scientifique (T. S. F. S.), dont la présente Union est issue.

Le Président du Comité Belge,	*Le Président de l'Union Internationale de Radiotélégraphie Scientifique,*
(*s.*) DE DONDER.	(*s.*) FERRIÉ.

Je m'empresse à présent de donner la parole à notre éminent et cher Président, M. le Général Ferrié, qui, grâce à sa compétence et à son dévouement, a porté si haut le prestige scientifique de l'U. R. S. I.

M. le Profr De Donder prie alors M. le Général Ferrié, Président de l'U. R. S. I., de prendre la présidence de la séance.

M. le Général Ferrié ouvre la séance et prononce le discours ci-après :

Messieurs,

J'ai tout d'abord l'agréable devoir de présenter les vifs remerciements de l'Union de Radiotélégraphie Scientifique à ceux dont nous avons l'honneur d'être les hôtes, pour l'accueil amical qu'ils ont bien voulu nous réserver, c'est-à-dire au Gouvernement belge, à l'Académie belge des Sciences et au Comité National Belge de Radiotélégraphie Scientifique.

Tout a été parfaitement organisé pour faciliter nos travaux autant qu'il est possible. De plus de nombreuses distractions, excursions ou réceptions ont été prévues pour constituer un dérivatif précieux à l'aridité du labeur qui nous attend. Au nom de tous, j'exprime notre profonde reconnaissance au Comité d'organisation et à son éminent Président M. De Donder.

Au cours de notre dernière Assemblée Générale à Washington, en 1927, plusieurs projets ont été établis concernant les statuts, l'organisation et le fonctionnement de notre Union. Nous devons les examiner à nouveau ici et prendre des décisions définitives.

Le Conseil International de Recherches nous a demandé, d'autre part, comme à toutes les Unions scientifiques qui lui sont rattachées, de donner nos avis sur les modifications à apporter aux statuts du Conseil lui-même. Nous aurons donc à échanger des vues à ce sujet.

Le Comité National Néerlandais nous a également consultés sur la possibilité d'établir éventuellement une collaboration suivie entre notre Union et le « Comité Consultatif Technique de Radiotélégraphie », dont la création figure dans les règlements administratifs internationaux qui ont été établis à Washington en 1927.

Quant aux questions financières et administratives concernant notre Union, elles feront l'objet du rapport de notre dévoué Secrétaire Général, M. Robert Goldschmidt, envers qui notre dette de gratitude s'accroît sans cesse et à qui je suis heureux de rendre un public hommage au nom de tous. Je désire aussi témoigner notre grande reconnaissance à son dévoué collaborateur, M. Paul Goldschmidt, Secrétaire Général adjoint.

Il me reste encore, Messieurs, à vous exposer quelques commentaires au sujet du travail scientifique qui nous incombe.

Lors de la fondation de notre Union, un des buts principaux que nous nous étions assignés était la recherche des lois qui régissent la propagation des ondes radiotélégraphiques, recherche qui nécessitait impérieusement une collaboration entre de nombreux observateurs répartis sur toute l'étendue de la surface du globe.

Le but de cette recherche n'était pas entièrement spéculatif, car nous espérions que la connaissance des lois de la propagation pouvait permettre aussi d'améliorer les communications radiotélégraphiques. Elle répondait au surplus à un besoin de l'esprit humain : connaître le mécanisme des phénomènes utilisés à des fins pratiques.

Les résultats déjà acquis semblent montrer que ces recherches ont une importance beaucoup plus grande qu'on ne pouvait le penser tout d'abord, car elles fourniront un nouveau moyen d'étudier les variations de l'activité solaire ainsi que certains phénomènes dont le siège est dans la haute atmosphère.

On ne disposait jadis, pour étudier l'activité solaire, que de l'observation directe de l'astre, mais on a constaté depuis que certains phénomènes terrestres étaient en relation directe ou indirecte avec cette activité : les variations du magnétisme terrestre, par exemple, comme l'ont confirmé tout récemment encore les travaux de notre collègue MAURAIN. C'est ainsi qu'on a été amené à conclure que les taches du soleil, seul indice accessible à l'observation directe, ne devaient être qu'une manifestation particulière, parfois déficiente, de l'activité solaire.

Les travaux de nos collègues AUSTIN et GREENLEAF PICKARD semblent bien montrer qu'il doit exister également une relation entre l'activité solaire et les phénomènes de propagation des ondes radiotélégraphiques.

Nous possédons donc un nouveau moyen d'étudier les variations de cette activité, et nos recherches, dont l'intérêt semblait au début devoir se cantonner dans un domaine spécial, vont devenir au contraire une aide puissante pour tous ceux qui s'occupent d'astrophysique. C'est ainsi que s'explique la présence parmi nous d'un certain nombre de savants dont les occupations habituelles semblaient bien étrangères à la Radiotélégraphie et dont la collaboration nous est infiniment précieuse.

Le fait que nos études sont étroitement apparentées à la Géophysique nous démontre qu'elles doivent présenter aussi toutes les difficultés que l'on rencontre dans toutes les branches de cette science.

Nous sommes forcés de constater, d'autre part, au fur et à mesure que nos procédés d'investigation augmentent de précision, que les lois de la propagation ne sont pas aussi simples qu'on l'avait supposé tout d'abord. C'est ainsi que nos collègues **Appleton**, **Breit**, **Taylor**, **Heising**, et d'autres encore, ont mis en évidence des phénomènes de réflexions multiples, ou d'échos, encore difficiles à expliquer.

Certaines circonstances locales viennent, en outre, modifier les lois générales de la propagation. **Austin** et **Bureau**, notamment, ont mis en évidence une influence locale de la troposphère, influence perturbatrice que de nombreuses expériences permettent probablement d'éliminer.

Pour utiliser nos observations il est donc nécessaire de leur appliquer les procédés qui ont si bien réussi aux astrophysiciens et aux géophysiciens. On est frappé, par exemple, en examinant le travail de **Maurain** sur les *Relations entre l'activité solaire et le Magnétisme terrestre*, de voir qu'il a fallu, pour mettre en évidence ces relations, utiliser les observations de quarante années et que ces relations auraient totalement échappé si l'on n'avait utilisé qu'un petit nombre d'années d'observations.

Remarquons aussi que l'astronome **Schwabe** n'a été amené à soupçonner l'existence d'un cycle solaire qu'après plus de trente années d'observation.

Il faut donc que nous accumulions nous aussi les observations, que leurs résultats soient centralisés par un organisme qui est le Secrétariat Général de notre Union, et que celui-ci puisse en assurer la publication et la distribution à tous les intéressés, d'une manière identique à celle qui est employée par les Observatoires de Géophysique et d'Astrophysique pour les résultats relatifs aux constantes magnétiques ou aux nombres de taches solaires, par exemple.

Quand les résultats ainsi accumulés seront en nombre suffisant, leur dépouillement pourra être fait avec fruit, et il deviendra moins difficile de déterminer exactement les relations entre l'activité solaire et les phénomènes de propagation des ondes radiotélégraphiques. La comparaison avec d'autres phénomènes, également en relation avec l'activité solaire, permettra probablement aussi de savoir quel est celui ou ceux de ces phénomènes qui retentissent directement sur la propagation des ondes. Une contribution importante sera ainsi apportée aux recherches générales concernant les relations entre les phénomènes solaires et terrestres.

Une collaboration constante avec les géophysiciens et les astrophysiciens est donc indispensable. Une Commission mixte a été créée dans ce but par le Conseil International de Recherches et s'est déjà réunie à plusieurs reprises pour établir des programmes de travaux. Elle a publié, en 1926, d'importants mémoires, et une nouvelle publication est prochaine.

Cette Commission recommande notamment d'organiser un certain nombre d'observatoires mixtes dans lesquels seraient faites simultanément des observations d'astrophysique, de géophysique et de propagation des ondes. Tous les membres de notre Union donneront certainement avec plaisir le concours qui leur sera demandé.

Le programme des travaux qui incombe à notre Union est donc très considérable, si l'on tient compte de toutes les recherches qui sont confiées à nos diverses Commissions. Je suis persuadé qu'il ne rebutera aucun d'entre nous et que dans tous les pays, nous trouverons les collaborateurs et les moyens d'action nécessaires pour mener notre tâche à bonne fin.

Un précieux encouragement nous est déjà venu du Conseil International de Recherches, dont l'éminent Président, M. Émile **Picard**, a bien voulu citer notre Union dans un de ses discours parmi celles dont le travail scientifique est le plus actif. Nous devons être fiers de cette appréciation et nous efforcer de toujours la justifier.

Après son discours, le Président prie M. Robert Goldschmidt, Secrétaire Général de l'U. R. S. I., de donner lecture de son rapport.

Rapport de M. Robert B. Goldschmidt, Secrétaire Général de l'U. R. S. I.

Report of Mr. Robert B. Goldschmidt, Secretary General of the U. R. S. I.

Monsieur le Président, Messieurs,

L'Assemblée Générale que l'U.R.S.I. a tenue à Washington en octobre 1927 a marqué une étape nouvelle dans le développement de ses travaux.

C'était, en effet, la première fois que les membres éminents qui composent ses Comités Nationaux s'y rencontraient au sein des différentes commissions qui avaient été créées à Bruxelles en 1922, c'est-à-dire dans les cadres déjà très parfaitement appropriés à la préparation et au développement des travaux en vue desquels notre Union a été constituée.

La réunion au sein de ces assemblées délibérantes, d'esprits aussi érudits, discutant de questions dont l'intérêt est scientifique exclusivement, devait donner aux assises de Washington une importance toute particulière, accentuée encore par l'exposé, en séance publique, de travaux dont l'intérêt est capital pour les progrès de la science et de la technique de la Radiotélégraphie.

L'Assemblée de Washington a rendu plus évidente encore, si possible, la nécessité de notre organisme, en montrant dans quelle large mesure il peut contribuer à ces progrès.

C'est pourquoi vous y avez reconnu qu'il était devenu nécessaire d'envisager les moyens de prendre différentes mesures d'organisation propres à mettre mieux au point encore les différents rouages du fonctionnement de l'U.R.S.I.; ces mesures, vous les avez consignées en un certain nombre de résolutions qui, les unes, pouvaient être mises directement en application, les autres, exigeaient qu'une réunion ultérieure vînt les consacrer par la constitution de rouages nouveaux.

Il appartient au Secrétaire Général d'abord de vous rendre compte des premières et des travaux qui s'y rattachent, ensuite, de solliciter la présente Assemblée de prendre toutes dispositions utiles en vue de la réalisation des secondes.

Publications et traductions. — Parmi les résolutions de 1927, l'une des plus importantes est celle qui se rapporte à la publication des travaux et des délibérations de l'Assemblée Générale et de ses Commissions.

Le Secrétariat a apporté tous ses soins à sa parfaite exécution, et, j'aurais voulu l'ajouter, à sa rapide exécution, si la rapidité d'exécution était compatible avec la rigueur des procédés qui s'imposent en matière de publications scientifiques.

Mon premier soin dans ce rapide compte rendu sera de rendre hommage à notre distingué collègue, M. Dellinger, qui a organisé avec le succès que vous savez le Congrès de Washington, et à qui nous devons de posséder les textes dont vous avez les exemplaires sous les yeux.

M. Dellinger a non seulement réuni les textes des études et délibérations, il les a aussi soumis au contrôle de leurs auteurs, et s'il n'avait dépendu que de lui, le Secrétaire Général fût entré en peu de jours en leur possession. Je saisis cette occasion d'adresser un pressant appel aux membres de cette Assemblée, pour qu'à l'avenir la mise au point des textes soit effectuée par eux sans perte de temps aucune; il suffit de l'absence ou de la carence d'une seule des personnalités qui ont pris part aux délibérations pour que tout l'ensemble d'une publication s'en trouve retardée.

Les textes étant réunis, les difficultés ne sont pas encore résolues. Vous avez décidé, en effet, et pour des raisons indiscutables en matière de rigueur scientifique, que les épreuves d'impression soient revues par les auteurs avant tirage. Il en résulte que le texte qui a déjà traversé dans les deux sens, soit la Manche, soit l'Océan Atlantique, soit même toute une succession de mers, de continents et d'océans successifs, les traverse une seconde fois dans les deux sens sous la forme d'épreuves imprimées; cependant aucun de ces quatre voyages (en réalité il y en a eu cinq) ne s'effectue à la vitesse de la propagation des ondes.

Ceci soit dit, Messieurs, pour que vous ne soyez pas tentés de considérer le Secrétariat Général comme étant coupable, ou tout au moins seul coupable, si les publications n'ont pu sortir de presse qu'après un délai assez important. Encore la situation ira-t-elle en s'améliorant d'année en année, du moins nous l'espérons.

Dans le domaine des publications, la tâche la plus ingrate que le Secrétariat ait eu à assurer est certainement celle des traductions. Ingrat, je le serais moi-même si je ne commençais par adresser des remerciements plus que mérités à M. le Général Ferrié et à M. Jouaust, d'une part, à M. Watson Watt, d'autre part, qui ont bien voulu contrôler ces travaux avec un dévouement et une sagacité auxquels je ne saurais assez rendre hommage. Les traductions que vous avez sous les yeux ne sont peut-être pas encore suffisamment parfaites, et vous estimerez peut-être à nouveau, avec nos éminents collègues italiens, qu'un traducteur est un traître. Mais aussi, nul mieux que vous ne sait combien les termes, même s'ils se rapportent à la même chose, changent de signification et de définition d'une langue à l'autre, et combien, en matière de traduction scientifique, l'homme scrupuleux est sujet au doute s'il tente d'être rigoureux.

Nous avons fait de notre mieux avec un maximum de soins et nous espérons qu'à ce titre vous nous pardonnerez les inévitables imperfections de l'exécution.

Quoi qu'il en soit, l'ouvrage en sept volumes que vous avez sous les yeux constitue un document d'un intérêt capital, que tous les milieux qui s'intéressent à la T. S. F. ont avantage à se procurer. Je me permettrai d'ajouter que son impression a engagé notre Union dans des dépenses très supérieures à ses ressources budgétaires. Il n'y a pas de doute que si les Comités Nationaux ne faisaient pas un effort considérable pour le répandre dans leurs pays respectifs, il ne serait pas possible de procéder dans l'avenir à de pareils frais. J'adresse donc un pressant appel à tous les Comités Nationaux pour qu'ils fassent des souscriptions fermes et immédiates.

Bibliographie et bibliothèque. — Une autre résolution de **1927** se rapporte au développement du service bibliographique et à l'institution d'une bibliothèque. Cette importante question fera l'objet d'un rapport spécial qui sera soumis à la Commission qui siégera à cet effet et que l'Assemblée plénière sera invitée à constituer immédiatement pour dégager le travail des autres assemblées. Grâce au concours de plusieurs Comités Nationaux, nous avons pu étendre considérablement les listes régulières de références bibliographiques. Nous espérons que ce service aura pu être utile à nos membres. A titre provisoire, nous avons utilisé le système de classement Dewey, qui avait été adopté non seulement en Amérique, mais également par la Sous-Commission spéciale du Comité National Français.

Nous avons cependant à enregistrer l'échec des négociations qui avaient été engagées avec le *Journal Télégraphique de Berne*, si éminemment représenté à Washington par M. Etienne, dont le décès survenu en mer, à son retour d'Amérique, a consterné ses nombreux amis; l'accord que nous avions tenté de contracter avec cette publication aurait considérablement facilité la diffusion de nos travaux; les successeurs de M. Etienne n'ont pas cru devoir ratifier les conventions provisoires que nous avions conclues et nous avons été contraints, de ce fait, de nous orienter dans une autre voie.

Extension de l'activité de l'U.R.S.I. — La sixième résolution de Washington est celle qui se rapporte aux démarches qui doivent aboutir, d'une part, à l'extension de l'U. R. S. I., d'autre part, à la réunion de fonds nécessaires à son activité nouvelle.

Votre Secrétaire Général n'a pas négligé le premier point, et priera le Comité Exécutif que vous avez à nommer tout à l'heure, d'examiner la situation actuelle, principalement en fonction de l'existence du « Comité Consultatif International Technique », créé à la Conférence de Washington et qui doit se réunir prochainement à l'initiative de l'Administration compétente des Pays-Bas.

Votre Comité Exécutif aura l'occasion également d'examiner dans quelle mesure les Comités Nationaux ont pu, en s'adressant aux Gouvernements, aux Académies, aux sociétés commerciales, aux groupements d'amateurs et de particuliers, recueillir des dons, des cotisations annuelles, des souscriptions aux publications de l'Union. Il pourra éventuellement, ainsi que le propose le Comité National Américain, établir un budget de dépenses sur lequel puissent s'appuyer ceux qui voudront bien s'occuper de ce travail de propagande si nécessaire au développement de nos travaux.

Dans le même ordre d'idées, une autre résolution (la dixième), a porté la cotisation des pays à 100 francs-or par unité. J'aurai l'occasion de vous signaler, en vous présentant le budget, qu'aucune des cotisations n'est encore rentrée pour 1927, ni sur l'ancienne base, ni sur la nouvelle, en sorte que notre situation budgétaire qui était très favorable l'an dernier, souffre aujourd'hui grandement de ce retard.

J'ajouterai que les difficultés financières sur lesquelles je me suis trouvé forcé d'attirer votre attention n'ont rien qui doive provoquer du pessimisme. Il ne s'est pas écoulé encore une année depuis que l'organisation nouvelle de l'U. R. S. I. a été élaborée à Washington, et il est tout à fait normal que les mesures d'exécution exigent pareil délai, lorsqu'il s'agit d'un corps dont les différents organes sont disséminés en des régions aussi éloignées que possible sur la sphère terrestre. En tout état de cause, les dépenses de l'U. R. S. I. sont très minimes, et elles ne sont inférieures aux recettes que parce que les Comités Nationaux ne se sont pas encore trouvés en mesure de réaliser le très léger effort qui leur est demandé.

J'en arrive à celles des résolutions de 1927 qui se rapportent à l'ordre du jour de la présente assemblée. Je les ai reprises dans ma lettre du 15 mai 1928 adressée à tous les Présidents des Comités Nationaux.

COMITÉ EXÉCUTIF. — D'après la douzième résolution, vous aurez à constituer le Comité Exécutif, composé d'un délégué de chaque Nation appartenant à l'Union, ce délégué étant désigné par les Comités Nationaux eux-mêmes. Le Comité Exécutif, étant chargé de l'étude de toutes les questions relatives à l'organisation et à l'administration de l'U. R. S. I., prendra, sous réserve de la ratification de l'Assemblée Générale à sa dernière réunion, des décisions au sujet des points suivants :

1° *Modification des statuts.* — Un projet de modifications aux statuts a été élaboré par le Bureau, afin de les conformer à la nouvelle organisation de l'U. R. S. I. Le Comité Exécutif aura à se prononcer à son sujet.

2° *Modification de la dénomination de l'U. R. S. I.* — Il aura également à décider de la nouvelle dénomination de l'U. R. S. I., qui prendrait le nom d' « Union Radio-Scientifique Internationale » adopté provisoirement.

3° *Désignation de Membres d'Honneur et d'un Président d'Honneur.* — Il fera également des propositions pour la désignation de Membres d'Honneur et d'un Président d'Honneur.

4° *Attribution de prix, médailles et diplômes internationaux.* — Il prendra toutes mesures utiles en vue de l'attribution de prix, médailles et diplômes internationaux.

5° *Création d'une Commission pour l'étude générale des oscillations.* — Il a été reconnu à Washington que l'étude des oscillations devait faire l'objet des travaux d'une Commission spéciale. Vous aurez à désigner les membres de cette Commission. Le Comité National Américain a émis le désir de voir celle-ci porter une autre dénomination.

6° *Renouvellement du Bureau.* — L'Assemblée Générale, en sa dernière réunion, aura, outre à ratifier les décisions du Comité Exécutif, à procéder au renouvellement du Bureau.

Il nous reste à faire aux Présidents des différentes Commissions des recommandations qui se rapportent à l'organisation du travail de celles-ci; elles résultent des directives exprimées par M. le Général Ferrié dans une lettre dont j'ai communiqué la teneur aux Présidents des Comités Nationaux et des Commissions.

Les Commissions s'inspireront utilement de cette considération, que le but des Assemblées Générales identiques à la nôtre n'est pas seulement de provoquer des discussions sur des sujets scientifiques qui leur auront été soumis, mais aussi et surtout de préparer des programmes de travail pour les recherches qui, sortant du cadre du laboratoire, nécessitent une collaboration internationale. Les Commissions pourront donc en premier lieu examiner les programmes de travail qui leur seraient éventuellement soumis, ce qui a été déjà le cas pour certaines d'entre elles. Elles se pénétreront de la nécessité de prendre au sujet de ces propositions des décisions fermes et d'arriver à la rédaction d'un texte aussi précis que possible qui serait soumis à la dernière réunion de l'Assemblée Générale. Les Commissions qui n'ont pas encore reçu de propositions pour un programme pourraient se borner, à une première réunion, à désigner un rapporteur chargé de l'établir, et laisser, en attendant, siéger les autres Commissions.

J'ai déjà demandé aux Comités Nationaux de désigner, parmi ceux de leurs membres qui assistent à cette Assemblée, des remplaçants pour ceux de leurs délégués aux différentes Commissions, dont nous avons à regretter l'absence. Tous les délégués prendraient part au vote sur les propositions, mais, en cas de divergences de vues, l'Assemblée Générale pourrait encore décider à leur sujet en votant cette fois par État.

Quand les Commissions auront terminé ce travail d'organisation des études futures, qu'on pourrait qualifier de « travail administratif », elles pourront aborder les discussions scientifiques. On ne saurait trop les engager à limiter ces discussions à des sujets bien déterminés, si elles désirent qu'elles soient fructueuses.

La présentation des mémoires proprement dits et leur discussion auraient lieu uniquement pendant les séances publiques, qui seront évidemment de ce chef les plus intéressantes de notre Assemblée Générale.

Dans ces conditions, je propose à l'Assemblée Générale de délibérer immédiatement sur les points suivants :

Constitution du Comité exécutif ;

Constitution d'une Commission spéciale pour l'étude des publications et de la Bibliographie ;

Désignation des délégués des Comités nationaux aux cinq Commissions, savoir : la Commission des Mesures et Etalonnages, la Commission de la Propagation des Ondes, la Commission des Atmosphériques, la Commission de Liaison, la Commission des Oscillations, la dénomination de cette dernière Commission restant à modifier.

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Liste des documents mis en circulation par le Secrétariat Général.

List of documents circulated by the General Secretary.

I. — *Caractéristiques et résultats des mesures des émissions U. R. S. I.*

a) Comité national américain :

Numéros 156, 162, 166, 170, 184.

b) Comité national français :

Numéros 152, 155, 160, 161, 163, 164, 165, 167, 173, 174, 176.

II. — *Autres documents.*

a) Comité national américain :

N° 153 : American Geophysical Union. Section of Terrestrial Magnetism and Electricity : Abstraits of Reports and Papers presented at Annual Meeting. April 1927.

N° 169 : On the influence of solar activity on radio transmission by Austin and Wymore.

N° 177 : Studies of high-frequency radio wave propagation by A. H. Taylor and L. O. Young.

N° 178 : On round the world signals by E. O. Hulburt.

N° 179 : The origin of the aurora borealis by E. O. Hulburt.

N° 180 : Report of the Chairman of the Commission on radio wave propagation : L. W. Austin.

N° 181 : Magnetostriction oscillators by George W. Pierce.

N° 182 : A dynamic study of magnetostriction by K. Ch. Black.

N° 183 : Long-wave radio receiving measurements at the Bureau of Standards in 1927.

N° 185 : An automatic recorder for measuring the strength of radio signals and atmospheric disturbances by Judson.

b) Comité national anglais :

N° 157 : A study of radio direction finding by R. L. Smith-Rose.

N° 158 : The Range of atmospherics.

N° 159 : Further measurements on wireless waves received from the upper atmosphere by R. L. Smith-Rose and R. H. Borfield.

N° 168 : On a method of determinating the state of polarisation of downcoming wireless waves by E. V. Appelton and G. A. Ratcliffe.

N° 175 : The polarisation of radio-waves by J. Hollingworth.

c) Comité national japonais :

N° 154 : Tables for facilitating the calculation of self-inductance of circular coil and mutual inductance of coaxial circular currents by H. Nagaoka and S. Sakurai.

N° 171 : Long distance radio receiving measurements by Tomozo Nakai.

N° 172 : Study on the operation of the multivibrator by Yasukazu and Shôgo Namba.

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Rapport financier.

Financial report.

Disponible au 1er septembre 1927 . . .fr.		13,968.01

Recettes :

Cotisations 1927 :		
Belgique		
Italie		
Etats-Unis		
Japon		
Union Sud-Africaine . . .		
Australie		
		7,292.10
		21,260.11

Dépenses :

Frais du Bureau administratif :		
Impression de documents. . .	3,122.95	
Ports, documents et correspondances	2,633.85	
Appointements du personnel. .	14,120.—	
		19,876.80
Reste disponible au 1er septembre 1927. .		1,383.31

Rentrées probables :

Arriérés cotisations 1927 . . .	2,200.—
Cotisations 1928 (base 100 fr. or)	30,000.—
Souscriptions publications A. G. 1927	

Dépenses engagées :

Publications et divers	50,000.—
Organisation A. G. sep. 1928. .	

N. B. — *L'état des recettes et des dépenses est établi en francs belges.*

Pour mémoire, le reliquat d'un crédit de 50,000 fr., ouvert antérieurement et mis par M. Robert GOLDSCHMIDT, Secrétaire Général, à la disposition de l'U. R. S. I., reste ouvert pour être affecté à des travaux extraordinaires ou à des études spéciales.

Ce crédit avait pour objet principal de faciliter les travaux de début de l'U. R. S. I., avant l'adhésion des différentes nations ; il a été fait rapport à l'Assemblée générale de 1922 sur les dépenses effectuées, rapport qui faisait ressortir le reliquat à 36,677 francs.

Le Président exprime son optimisme au sujet de la rentrée des cotisations restant à verser et suggère de passer cette question au Comité Exécutif.

Il propose ensuite de constituer celui-ci.

CONSTITUTION DU COMITÉ EXÉCUTIF.

Après délibération, le Comité Exécutif est constitué comme suit :

Président :	Général FERRIÉ.
Australie :	Prof^{r} MADSEN
Belgique :	Prof^{r} DE DONDER.
États-Unis :	Dr. AUSTIN.
France :	Général FERRIÉ
Grande-Bretagne :	Prof^{r} APPLETON.
Italie :	Prof^{r} VANNI.
Japon :	Prof^{r} NAGAOKA.
Norwège :	(Réservé.)
Pays-Bas :	BLAND VAN DEN BERG.
Portugal :	(Réservé.)
Union Sud-Africaine :	CAMPBELL.

Le Comité Exécutif se réunira immédiatement après la séance et décidera de sa prochaine réunion.

CONSTITUTION DES COMMISSIONS.

On passe ensuite à la constitution d'une Commission spéciale pour l'étude des publications et de la Bibliographie.

M. le Président, vu le programme surchargé de l'Assemblée Générale, propose de confier au Comité Exécutif la création d'une Commission ou d'un sous-comité composé de deux ou trois membres chargés d'étudier cette question et de présenter des propositions à l'Assemblée Générale.

Le point suivant de l'ordre du jour a trait à la constitution des diverses Commissions; il est décidé que chaque Commission élira dans son sein un président dont le choix sera ratifié par l'Assemblée Générale.

COMPOSITION DES COMMISSIONS :

Commission I.

Méthodes de mesures et étalonnages.

MEMBRES :

MM. le Dr. Dye	Angleterre.
Ing. Corteil	Belgique.
Dr. Hull	États-Unis
Prof^r Mesny	France
Prof^r Vanni	Italie.
Prof^r Nagaoka	Japon.
Dr. Campbell	Afrique du Sud.
Dr. van der Pol	Pays-Bas.

ADJOINT :

Ing. Braillard.

Commission II. — Propagation des ondes.

MEMBRES :

MM. Dr. Smith-Rose	Angleterre.
Prof^r De Donder Prof^r Janne	Belgique.
Dr. Austin	États-Unis.
Prof^r Mesny	France.
Prof^r Vanni	Italie.
Prof^r Nagaoka	Japon.
Dr. Campbell	Afrique du Sud.
Dr. van der Pol	Pays-Bas.

Commission III. — Perturbations atmosphériques.

MEMBRES :

MM. Dr. Watson Watt	Angleterre.
Ing. Philippson	Belgique.
Dr. Snyder	États-Unis.
Cap. Bureau	France.
Prof^r Vanni	Italie.
Prof^r Nagaoka	Japon.
Dr. Campbell	Afrique du Sud.
Dr. van der Bilt	Pays-Bas.

Commission IV. — Liaison avec les amateurs, etc.

MEMBRES :

MM. Dr. Rayner	Angleterre.
Colonel Wibier	Belgique.
Prof. Kennelly	États-Unis.
Ing. Brenot	France.
Prof^r Vanni	Italie.
Dr. Campbell	Afrique du Sud.
Prof^r Nagaoka	Japon.
Dr. van der Bilt	Pays-Bas.

Commission V. — Radiophysique.

MEMBRES :

MM. Prof^r Dacos	Belgique.
Prof^r Kennelly	États-Unis.
In^g Le Corbeiller Ing. Salomon	France.
Prof^r Vanni	Italie.
Prof^r Nagaoka	Japon.
Dr. Campbell	Afrique du Sud.
Dr. van der Pol	Pays-Bas.

Le Comité National Anglais a décidé de ne pas désigner de délégué pour cette Commission.

La séance est suspendue pendant quelques instants pour permettre aux différentes Commissions d'élire leurs présidents.

Les désignations suivantes sont proposées et approuvées à l'unanimité par l'Assemblée Générale :

Commission	I :	Dr. Dye.
»	II :	Dr. Austin.
»	III :	Dr. Watson Watt.
»	IV :	Prof^r Vanni.
»	V :	Dr. van der Pol.

Afin de permettre à chacun des membres d'assister à toutes les séances, on décide que les réunions des Commissions n'auront pas lieu en même temps, mais les unes après les autres dans l'ordre I, II, III, V et IV.

ORGANISATION DE LA SÉANCE PUBLIQUE.

On délibère ensuite sur l'organisation de la Séance Publique qui aura lieu le jeudi 13 septembre. On décide de donner lecture de tous les mémoires présentés à l'Assemblée Générale et dont la liste est publiée dans le premier fascicule du présent volume. Le Secrétariat Général établira le programme de la Séance Publique en groupant ensemble les mémoires traitant de sujets connexes.

MESSAGE DE S. M. LE ROI DES BELGES.

Le télégramme ci-après a été reçu en réponse à celui expédié par l'Assemblée Générale à S. M. le Roi des Belges :

> Messieurs le Général Ferrié et De Donder, Présidents de l'Union Internationale de Radiotélégraphie Scientifique et du Comité Belge. Le chaleureux message que vous lui avez adressé à l'occasion de l'Assemblée Générale de l'Union Internationale de Radiotélégraphie Scientifique a particulièrement touché le Roi. Sa Majesté m'a chargé de vous transmettre, ainsi qu'à tous ceux dont vous vous êtes fait l'interprète, l'expression de sa vive gratitude.
>
> *Chef Cabinet Roi.*

Assemblée Générale du 15 Septembre 1928

General Session, September 15, 1928

La séance est ouverte à 10 h. 10, sous la présidence de M. le Général Ferrié.

1° Résolutions du Comité Exécutif.

M. le Président. — Messieurs, votre Comité Exécutif a étudié un certain nombre de questions dont il va vous être rendu compte.

a) MODIFICATION DE LA DÉNOMINATION DE L'U. R. S. I.

Le Comité Exécutif vous propose d'appeler notre groupement « Union Radio-Scientifique Internationale ». On a objecté que le mot « Radio » n'était ni anglais, ni français. En ce moment, étant donnés les progrès constants de la technique et particulièrement de la technique de la radio, le besoin de mots nouveaux se fait sentir, et nous pensons que c'est pour nous une occasion d'adopter un mot nouveau. Nous vous proposons donc la nouvelle dénomination de l'U. R. S. I.

Aucune objection n'étant présentée, la proposition du Comité Exécutif est adoptée.

b) MODIFICATION DES STATUTS.

M. le Président. — Nous ne pouvons modifier les statuts de notre Union sans l'approbation du Conseil International de Recherches.

Nous avons élaboré des statuts qui seront distribués pour examen et avis à tous les Comités Nationaux, par les soins du Secrétariat Général. Quand nous aurons reçu l'accord de ceux-ci, nous soumettrons notre projet au Conseil International de Recherches.

c) BUDGET.

Les propositions présentées par la Commission financière sont acceptées.

d) LETTRE DU COMITÉ NATIONAL HOLLANDAIS RELATIVE AU COMITÉ CONSULTATIF INTERNATIONAL TECHNIQUE.

M. le Président. — Nous arrivons maintenant à la question qui a été posée par le Comité National Hollandais et appuyée par une letrre de M. Arendt, Directeur des Télégraphes du Reich, Président de la délégation allemande à la Conférence Radiotélégraphique Internationale de Washington.

M. Bland van der Berg va vous exposer la question.

M. Bland van der Berg. — Il existe un point plus ou moins difficile à établir, c'est celui des relations qui doivent exister entre le C. C. I. qui se réunira en Hollande, et l'U. R. S. I. L'Administration néerlandaise, qui reconnaît l'utilité de l'U. R. S. I., a étudié cette question et est arrivée à la proposition que je vais vous lire. C'est une déclaration formelle, qui, je crois, donnera une solution à la question.

Suivant l'article 33 du règlement général annexe à la Convention Radioélectrique Internationale de Washington, l'Administration des Pays-Bas est chargée d'organiser la première réunion du Comité Consultatif International Technique des communications radioélectriques et d'établir le programme des travaux de cette réunion. La Commission qui élabore ces travaux s'est mise en rapport avec le Nederlandsche Radio Genootschap, Comité National Néerlandais de l'U. R. S. I., et non avec l'U. R. S. I., parce qu'elle est d'avis que le concours qu'elle invoque doit se limiter à ce Comité National. En agissant autrement les administrations étrangères pourraient y voir un acte peu courtois à leur égard. L'Administration néerlandaise reconnaît la haute compétence de l'U. R. S. I. dans cette matière; elle veut en donner une preuve et c'est ainsi qu'elle s'est proposé de poursuivre la réalisation des projets suivants concernant les relations entre le C. C. I. Radio et l'U. R. S. I.

A la convocation de la première réunion du C. C. I., par l'intermédiaire du Bureau international de Berne, l'Administration néerlandaise relira la proposition d'introduire l'U. R. S. I., de sorte qu'elle puisse participer aux délibérations, et de lui accorder une voix consultative. En outre, l'Administration néerlandaise a l'intention de proposer aux administrations qui seront réunies à la première session du C. C. I., et qui pourront partager sa manière de voir, de se déclarer en principe disposées à favoriser que, soit à l'occasion de la Conférence internationale à Madrid (en vue de la revision de la Convention de Washington), soit à la première occasion légale qui se présente plus tôt, qu'il soit possible que les sociétés scientifiques de composition internationale sans restriction, qui s'occupent de radio, puissent participer aux réunions du C. C. I. comme membres avec voix délibérative.

En principe, l'U. R. S. I. assisterait aux réunions du C. C. I. et serait consultée. Nous espérons vivement que cette proposition vous agréera et que l'U. R. S. I. acceptera notre invitation.

D^r Van der Pol. — M. le Président, vous me permettrez, en tant que Président de la Nederlandsche Radio Genootschap, de remercier M. Bland van der Berg pour la peine qu'il a prise dans cette question délicate.

M. le Président. — L'U. R. S. I. et moi-même avons le devoir de remercier très vivement M. van der Berg et le Comité National Néerlandais d'avoir pensé à mettre en avant la possibilité d'une collaboration entre l'U. R. S. I. et le C. C. I. Toutefois, il y a lieu de remarquer que ces deux groupements sont complètement différents. Le C. C. I. créé à Washington a un caractère exclusivement technique, tandis que le caractère de notre Union est purement scientifique. Cependant nous pouvons affirmer, je crois, et je vous demanderai votre avis, que nous sommes prêts, en corps et individuellement, à donner notre concours en ce qui concerne la radio-scientifique, lorsqu'il nous sera demandé.

Je vous propose donc de prier le Comité Néerlandais de dire officiellemnet que l'U. R. S. I est prête à donner son concours, si on le lui demande, à des travaux scientifiques.

Quelqu'un a-t-il une observation à présenter?

M. Bland van der Berg. — C'est avec un très vif plaisir que je transmettrai à l'Administration néerlandaise votre réponse, pour laquelle je vous remercie.

e) DÉSIGNATION D'UN PRÉSIDENT ET DE MEMBRES D'HONNEUR.

M. le Président. — Notre ordre du jour appelle ensuite la désignation de Membres d'Honneur et d'un Président d'Honneur.

Il a paru préférable au Comité Exécutif, au point de vue international, de supprimer cette éventualité pour éviter des difficultés et des froissements. Je tiens à faire remarquer, toutefois, que chaque Comité National a toute latitude de nommer des Présidents ou des Membres d'Honneur.

Aucune objection n'étant présentée, il est décidé de ne nommer ni Président d'Honneur ni Membres d'Honneur pour l'U. R. S. I.

f) ATTRIBUTION DE PRIX, MÉDAILLES ET DIPLOMES INTERNATIONAUX.

M. le Président. — L'ordre du jour appelle ensuite la question de l'attribution de prix, médailles et diplômes internationaux.

Notre situation financière étant très pénible, je crois que nous pouvons remettre ces largesses à l'avenir.

Aucune objection n'étant faite, cette proposition est adoptée.

g) BIBIOGRAPHIE.

M. le Président. — M. le Prof^r Appleton a soumis au Comité Exécutif une proposition fort intéressante qui a été appuyée par le Secrétaire Général et acceptée par le Comité Exécutif. Je prie M. le Prof^r Appleton de nous représenter ici sa proposition.

Prof^r Appleton. — I propose quite briefly that the bibliography of the U. R. S. I. would be an extended form of the bibliography which is at present produced in « Experimental Wireless ». The editor of « Experimental Wireless » would cooperate with the U. R. S. I. so that it will be possible to make this bibliography greater and more useful than it is at present. A notable assistance will be the cooperation of some countries like Italy, Japan and Holland for which certain references have been lacking in the past.

M. le Président. — Il est entendu que cette bibliographie ainsi que les tirés à part porteront l'étiquette de l'U. R. S. I. et non pas celle de la revue.

D^r^ Van der Pol. — Are the subjects to be sent directly to the editor? Would the National Committees of which languages are not so well known as English and France, have to send the extracts and notes in English?

Prof^r^ Appleton. — I ought to state that since the bibliography of Experimental Wireless is prepared by the Radio Research Board, it would be desirable to send the notes in English if possible and it would be fitting that the name of the Radio Research Board should be mentionned on the bibliographies. It is a question which could be arranged by the Secretariat Général and the British National Committee.

M. le Président. — Les Comités Nationaux qui établiront des bibliographies les enverront au Secrétariat Général, qui les transmettra à l'éditeur. Des tirés à part seront distribués aux Comités Nationaux. Les détails d'exécution peuvent être mis au point par M. le Prof^r^ Appleton et notre Secrétaire Général.

M. le Secrétaire Général. — Je suis très heureux de la proposition de M. le Prof^r^ Appleton et j'estime que nous pouvons tous l'en remercier. Cette façon de procéder nous évitera un travail long et laborieux. Je ferai tout mon possible pour que la centralisation des références bibliographiques se fasse rapidement.

Peut-être un jour y aura-t-il moyen que les titres de tout ce qui est édité et de nature à nous intéresser nous soient communiqués immédiatement et gratuitement par les Sociétés de Radiotélégraphie.

Je dois vous entretenir d'une autre question : M. le Prof^r^ Austin a envoyé au Secrétariat Général des courbes très intéressantes, mais qui malheureusement ne peuvent pas être publiées intégralement. Nous avons reproduit ces courbes sur des films qui peuvent être mis entre les mains de tout le monde. Si cette façon de procéder rencontre votre assentimment, le Secrétariat Général pourrait éditer ces films et les fournir au prix de cinquante courbes pour 5 francs belges.

M. le Président. — Je pense que nous acceptons tous avec grand plaisir la proposition de M. R. Goldschmidt.

Pour ce qui est de la bibliographie, nous avons tous admis que notre Secrétaire Général s'entendra avec M. le Prof^r^ Appleton pour la mise au point des détails d'exécution.

Prof^r^ Austin. — I would like to know which apparatus is to be used for the projection of the films.

M. R. Goldschmidt. — N'importe quel appareil, d'une valeur minime ne dépassant pas 10 dollars.

Prof^r^ Mesny. — Je ne veux pas prolonger la discussion sur la question bibliographie, mais je serais heureux de consulter l'U. R. S. I. sur une proposition dont les détails devront être réglés ensuite entre le Prof^r^ Appleton, le Secrétaire Général et le Comité Français. Si un arrangement pouvait intervenir entre l' « Experimental Wireless » et la revue l' « Onde Électrique » nous pourrions publier également la bibliographie en langue française.

D^r^ Van der Pol. — I support the proposal of Prof^r^ Mesny.

Prof^r^ Appleton. — I think that the editor of « Experimental Wireless » will agree.

M. le Président. — Nous remercions vivement ces Messieurs et nous prions le Secrétaire Général d'étudier la question avec MM. Appleton et Mesny.

Nous continuons notre ordre du jour; je vous propose d'admettre que les travaux scientifiques envoyés à l'U. R. S. I. ne soient plus traduits et soient publiés uniquement dans leur langue originale, afin de simplifier le travail du Secrétariat Général.

Cette proposition est adoptée.

2° Résolutions des Commissions. Désignation des Présidents et des membres des Commissions.

M. le Président — Je demande que chaque Président de Commission veuille bien nous donner un résumé de son rapport; la lecture entière nous prendrait trop de temps.

Les Présidents des Commissions donnent un résumé des rapports dont les textes suivent.

* * *

Rapport de la Commission I.

Report of Commission I.

The resolutions were as follows :

1. Arrangements will be made with Dr. Hoyt Taylor of the Naval Research Laboratory, « Bellevue » Anacostia D. C. for the transmission of a regular series of signals on short waves (15 metres wave-length or 20 megacycles per sec.) for the purpose of effecting international comparisons of frequency standards in this region of wave-length.

The times and modes of transmission will be decided by correspondence and probably a little more work.

2. Negotiations will be made with the British Broadcasting Corporation and, if satisfactory, the following arrangements will be made with them :

a) To transmit from the broadcast station at Daventry (5 GB) unmodulated waves according to a programme for the purpose of international radio frequency comparisons within range of the station in the region of radio frequency, 610 Kc/s (492 metres, wave-length).

b) To transmit from the same station a programme of modulated waves, the modulation being produced by a very steadily operated tuning fork of frequency in the near vicinity of 1 000 cycles per second. This transmission will be of such duration and character that the frequency of the modulation may be compared with the frequency of a tuning fork such as is used at Brussels as the standard for all the European broadcast stations and elsewhere on multivibrator wavemeters, etc.

This modulation frequency will be accurately measured in England at the National Physical Laboratory and in other places where accurate absolute measurements in terms of astronomical time can be made.

3. Arrangements will be made with Dr. Hull formerly of the Bureau of Standards and now of Radio Frequency Laboratories Inc. Boonton, N.J. for the supply on loan to the U.R.S.I. of a self-contained piezo-electric quartz oscillator with temperature-control and of such quality as to serve as a standard of radio-frequency to be sent in circulation from one national laboratory to another in a circuit continuously.

The responsibility or action in these programmes rests with the President of Commission I who will take the necessary initiative and will forward copies of correspondence to the General Secretary at Brussels.

In addition it is hoped to undertake in Great Britain a comparison of various methods of current measurement at extra high frequencies (greater than 6 megacycles per second).

Descriptions of various methods of measurement of capacity, inductance, effective resistance, properties of dielectrics, etc., will be forwarded to the General Secretary who will redistribute them to all interested.

D. Dye.
(Chairman.)

Note : Dr. Dye was elected president of Commission I in place of Prof. H. Abraham who expressed the desire to retire from the presidency.

* * *

Rapports de la Commission II.

Reports of Commission II.

Première Sous-Commission.

First Sub-Commission.

Terms of Reference : To consider the effect of the ground in signal intensity measurements with a loop.

Conclusions : 1. The electric field intensity (or the magnetic field intensity) is correctly determined in the usual way by measuring the electromotive force produced by the waves. This electromotive force is the same whether calculated as being a result of the electric or magnetic field of the waves whateter be the electrical constants of the ground provided we are dealing with a steady state at some distance from the transmitter.

2. In normal cases this E. M. F. is the cause of a current flowing in the aerial circuit. This current undoubtedly influences the transmitter but for practical purposes the reaction of receiver on the transmitter is negligible. It is therefore not necessary to use a high-resistance receiving circuit to keep the received antenna current small.

3. In all cases we measure with a loop antenna the rate of change of the magnetic field of the waves. This magnetic field may be due to both ground waves and downcoming waves. The ground wave is calculated according to Sommerfeld's analysis while the downcoming wave produces a magnetic field which can be calculated according to the laws of optical reflection from metals if the :

a) angle of incidence,
b) conductivity of the ground,
c) dielectric constant of the ground,
d) permeability of the ground,

are known at the receiving station.

It should clearly be understood that at the ground one must add the intensities of the downcoming ray and its reflected component together with that of the ground wave vectorially.

It should further be understood that the above results are only valid when the loop is shielded from antenna-effect and its dimensions are small compared with the wave-length and the distance from the ground small compared with the wave-length.

4. The valuable suggestion was made to the sub-committee by Professor Nagaoka that it might be desirable to make observations on the same station at approximately the same distance on land and on sea to see if there were marked differences due to the differences in the electrical constants of land and sea.

Summary. The usual procedure of measuring signal intensities at the ground may be justified on theoretical grounds. The presence of the loop does not distort the field acting on the loop, though it does distort the field acting on some circuit in the vicinity. The field acting on this third circuit may be regarded as the vectorial sum of that due to the incident waves together with the waves generated by the receiving loop.

DEUXIÈME SOUS-COMMISSION.

SECOND SUB-COMMISSION.

Terms of Reference : 1. To consider the desirability of making continuous automatic records of signal intensities received from commercial and other stations.

2. To consider the types of special transmissions that are required for making signal measurements.

3. To consider the Proposals of the French National Committee as outlined on paper A.G.1. (Annexe 1, page 23).

Decisions : a) That it is desirable to make automatic records of long wave commercial signals at a distance of 600 to 1 000 miles. Such measurements should be made using a loop antenna. If possible, however, additional information relating to the angle of incidence of the downcoming waves might be obtained by using antenna and loop systems alternately the change from one system to the other being made automatically. If it were possible further to take records on three loops (one in the maximum position and the other inclined symmetrically at angles of 45° to it) information about the polarization of the waves might be obtained.

b) That it is desirable that records of telephony stations operating through the sunset period be made. These should be made :

a) on the long wave band at a distance of 200—400 miles;

b) on the medium wave band at a distance of 50—100 miles.

The examination of (2) and (3) was postponed to the next meeting of Commission II as it was considered that these questions were best discussed when as many countries as possible were represented.

TROISIÈME SOUS-COMMISSION.

THIRD SUB-COMMISSION.

Terms of Reference : To consider the proposals of the French National Committee contained in Document: 1928 A.G. 1. (Annexe 1, page 23).

I. — It was agreed that the first proposition dealing with long wave transmissions was now covered by the proposals of sub-committee II for the continuous recording of signal intensity, and that there was no need for further special measurements.

II. — *a*) It was agreed to support the second proposition and to recommend the Commission to arrange for a series of measurements or observations of signal intensity to be made on four transmitting stations to be received in as many countries as possible.

b) It is recommended that wherever possible, actual measurements of signal intensity should be made, but failing this, estimates of the intensity may be made by an audibility method. It is desirable that a description of the apparatus employed at each observing station should be circulated among all the observers participating in this work.

c) The transmitting stations provisionally selected for observations are : Arlington, Schenectady, Eindhoven (P C J J.), and a station in Japan.

In the case of Arlington the time signals transmitted at 0300 and 1700 G.M.T. would be utilised and these times would fix the beginning of the period of observation. It is recommended that the respective authorities controlling the other three stations be approached to ascertain the possibility of provinding special transmissions of a duration of 15 minutes within the periods 0310 to 0410 and 1710 to 1810 G. M. T.

d) The desired conditions of these transmissions are :

1° The wave-length to be between 14 and 40 metres.

2° The transmitter should have a constant power output and work with a fixed antenna system during the period of one or more years which the observations are intended to cover. If it is necessary to alter the antenna system at any time; it is requested that advance information be given, so that a comparison test may be arranged between the old and new system. In any case it is asked that information of the dimensions, configuration, etc., of the antenna system may be supplied where possible.

3° The antenna current is to be recorded at every transmission.

4° The transmissions for a duration of 15 minutes, are to be given on one day of the week between Monday and Friday inclusive.

e) At the receiving station it is recommended that measurements of the signal intensity of the four stations should be made on the day selected for the special transmissions, and that the intensity of the Arlington signals should be measured on as many other days as possible.

III. — The third proposition was agreed to, viz.; that the tabulated results of the measurements should be forwarded monthly to the Secretary General for circulation among the members of the Union.

IV. — It was agreed to support the fourth proposition requesting the publication of the results as soon as possible, for the use of other radio workers and of physicists occupied with the study of solar and terrestrial phenomena.

The meeting of this sub-committee was attended by MM. Mesny, Nagaoka, Snyder, and Smith-Rose.

* * *

Rapport de la Commission III.

Report of Commission III.

The Commission met on Wednesday 12th, and Friday 14 th, Sept. Thanks to the very complete preparatory discussions, presided over by M. Mesny at Washington, the Commission was able to proceed at once to the discussion of limited concrete proposals. These were contained in two documents previously circulated, viz.; « Propositions du Comité Français de Radiotélégraphie Scientifique relativement à l'Etude des Atmosphériques (Annexe 2, page 26) », and a similar document from the British National Committee,

« International Programme of Observations on Atmospherics » (Annexe 3, page 28).

The Commission adopted the French proposal for fixed hours of observation of atmospherics, the fixed hours being, for Central and Western Europe, 9 h., 15 h. and 23 h. G.C.T., for the rest of the world, 9 h., 15 h. and 23 h. zone time, and also 23 h. G.M.T.

On the Second French proposal, for an absolute measure of the « activity » of atmospherics, a sub-committee was appointed to consider the details, the members being Messrs Bureau, Kennelly, van der Pol, and Watson Watt.

At the second sitting of the Commission this sub-committee report was submitted by the Chairman, who said that he had invited Messrs Parkinson and Snyder to be present at its meeting.The following recommandations, presented by the sub-committee, were adopted by the Commission, viz.:

a) That the general study of the distribution in the radio spectrum of the energy of atmospheric disturbance should be undertaken fortwith;

b) That the quantity to be measured should be the mean field strength, expressed in microvolts per metre, of the atmospheric disturbance within specified frequency bands, the mean to be measured over a period of time to be specified. The field strength should be referred to that electromotive force of the mid-frequency of the frequency band, introduced from a local source into the antenna circuit, wich gives the same deflection of the ultimate recording instrument;

c) That the apparatus used in all countries for this measurement should be rigoroiısly indentical, and that the identical aerials used should be symetrical T-antennas of a single wire, 50 m. long and 20 m. high with a coupling resistance of 20 000 ohms;

d) That the detailed design and specification of a recording apparatus to operate simultaneous on six frequency bands should be prepared by Messrs Snyder and Watson Watt;

e) That the frequency bands first explored should lie between 1 000 kc. and 20 kc. but that the apparatus should be capable of operating on 20 000 kc. and that recording in the higher frequency bands should be regarded as of extreme urgency;

f) That a constant band width of 25 cycles is desirable throughout the installations;

g) That the generous offer, conveyed by M. Snyder, that the General Electric Company of America will provide, free of cost to the U.R.S.I. and its constituent National Committees, the installations required for these measurements, should be accepted, and, that the thanks of the Commission for this undertaking should be recorded.

The Commission charged the Sub-Commission, consisting of Messrs Snyder and Watson Watt, with the additional duty of allocating and distributing the apparatus.

The third French proposal comprised two portions, one dealing with recording, and one with aural reception. It was agreed that as the organisation of the subsidiary recording networks was one which did not essentially involve international standardisation, it should be left to National Committees to arrange for such work where possible. With regard to aural observations, it was agreed that National Committees should be asked to invite radiotelegraphic administrations, services and commercial companies to communicate to them logs of atmospheric disturbance, with special reference to the selected « fixed hours », and to the time of sudden changes in the intensity or nature of the disturbance.

The fourth proposal, for the selection of frequency bands centred on 20, 65, 130, 4 000 and 12 000 kc. was approved, with the addition of a band centred on 1 500 kc., but the sub-commission was instructed to regard this specification as a general guide only, and to exercise their discretion in selecting bands free from traffic interference.

The Commission accepted the fifth proposition, envisaging the preparation of charts of isoploths and isochrones of atmospheric disturbance, as indicating valuable methods of study.

Passing to the British proposals, the Commission found that items *a*, *b*, d_1 and d_2, had been covered by the adoption of the French programme, while d_3, (relation with geophysical phenomena) was approved in principle, without the discussion of details. Time did not permit of the discussion of c (classification), and d_3 (radiogoniometry of atmospherics). On the latter the Chairman remarked that the Navy Department of the United States of America was undertaking observations with the Cathode Ray Direction Finder.

The British proposal d_4 (use of broadcast matter as a time base for observations on atmospherics), was remitted to Commission IV, as being essentially a matter for cooperation with amateur and other observers.

It will be seen that the main result of the Commission's work in the Brussels meeting has been the planning of the first international network for strictly quantitative recording of atmospherics throughout the twenty-fours hours. The number of variables controlling the disturbance is so great, and the mechanism of disturbance so complex, that no general method for comparing results from non-identical apparatus can yet be suggested. But it is at last possible, thanks to the very generous assistance promised by the G.E.C. of America, to ensue that a sufficient network of identical installations will be distributed throughout the world to provide a first general survey of disturbance in relation to place, time, and frequency. It is hoped that the individual units of this work will also serve to link together national networks operating, on a less open spatial scale, with less stringent and therefore less costly methods.

The Commission asks, in general, for confirmation by the General Assembly of its work, as reported in this summary, and in particular for a resolution offering the cordial thanks of the U.R.S.I. to the General Electric Company of America for their generous undertaking to provide the costly apparatus required for the first international recording network here outlined.

(s.) R. A. Watson Watt.

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Rapport de la Commission IV.
Report of Commission IV.

1. Étant données la complexité des phénomènes de radiotransmission et de géophysique, de physique solaire et de météorologie, et la corrélation existant entre ces phénomènes, la collaboration internationale entre les personnes qui s'occupent de ces sciences semble être absolument nécessaire pour arriver à un progrès satisfaisant.

C'est pourquoi les membres de la Commission sont d'avis que des observations simultanées des phénomènes se rapportant aux sciences ci-dessus indiquées seront de grande efficacité pour la solution des différents problèmes, tant théoriques que pratiques, à résoudre.

La Commission IV exprime le vœu que le Secrétariat Général de notre Union puisse étudier les moyens les plus convenables pour réaliser ce programme et obtenir la coopération des différentes organisations scientifiques internationales.

2. Pour le même but, et pour permettre aux différents observateurs et en particulier aux amateurs de prêter leur concours, on propose de publier des bulletins d'information annonçant d'avance soit les phénomènes ayant lieu à des époques bien déterminées, tels que les éclipses solaires, par exemple, soit les perturbations magnétiques, électriques ou météorologiques qu'on peut prévoir d'une manière quelconque. Il serait désirable qu'on utilisât un code à étudier.

En ce qui concerne les phénomènes se rapportant plus particulièrement à la météorologie, la Commission IV, prenant en considération le plan déjà présenté l'année dernière à Washington par M. Bureau et ayant trouvé pour la réalisation de ce plan des difficultés en ce qui concerne les transmissions des stations en Europe, propose que les émissions des Etats-Unis à Bellevue et à Arlington puissent être utilisées, et propose aussi que des démarches en ce sens soient faites.

Il est entendu que lorsque l'Institut Belge de Recherches Radioscientifiques sera dans les conditions voulues, on pourra faire les démarches afin que ses émissions soient utilisées en Europe.

3. Pour ce qui se rapporte enfin à l'observation et à la coordination de l'étude des parasites, cette question a été considérée d'une manière particulière par la III^e Commission, aux conclusions de laquelle on peut se référer. La Commis-

sion IV, examinant la question au point de vue des appareils simples et peu coûteux dont les amateurs peuvent disposer, a examiné la méthode qui est maintenant en cours d'exécution au service météroroloqique radio-atmosphérique italien, et propose la méthode de l'observation téléphonique des syllabes coupées pendant les émissions de radio-diffusion, méthode qui a déjà donné de bons résultats et qui a l'avantage de ne pas exiger des émissions particulières.

VANNI.

* * *

Rapport de la Commission V.

Report of Commission V.

Les travaux de la Commission V ont consisté en deux séances de discussions, le 12 et le 14 septembre, et en la présentation de mémoires au cours des séances publiques du 13 septembre.

Au cours des séances des 12 et 14 septembre, on a discuté le nom à donner à la Commission, et après quelques échanges de vues le nom de « Commission de Radiophysique » a paru préférable au nom de « Commission des Oscillations » qui avait été proposé à Washington. Nous avons l'honneur de présenter ce nom à l'approbation de l'Assemblée Générale.

Le programme de la Commission a été discuté au cours de sa première séance. Il a semblé qu'il pouvait être divisé en étude des systèmes linéaires et non-linéaires; les premiers comprenant les systèmes dont tous les éléments oscillent à une fréquence unique, qu'ils soient d'ailleurs de caractère mécanique ou électrique, tels que les filtres (électriques, mécaniques ou acoustiques), les haut-parleurs, les résonateurs à cristal de quartz ou à magnéto-striction, etc., les seconds comprenant tous les systèmes à transformation de fréquence, tels que les détecteurs, modulateurs, multiplicateurs et démultiplicateurs de fréquence, les générateurs alternatifs à source d'énergie continue, etc.

La nomenclature, les définitions et les symboles relatifs à ces systèmes paraissent entrer également dans le cadre de la Commission. Notre Président, le Général Ferrié, a fait connaître que la Commission Électrotechnique Internationale se proposait de consulter l'U. R. S. I. sur les questions de ce genre touchant la Radio et la V^e Commission s'offre à préparer les réponses éventuelles à un pareil questionnaire.

Au cours de la seconde séance deux questions ont été amorcées : 1° la propagation d'un signal périodique dans un milieu dont les propriétés en tous points sont fonctions du temps, et 2° la relation entre la distribution du courant dans une antenne ouverte et la radiation de cette antenne.

Sur la première question, MM. Kennelly, Mesny, Appleton, Le Corbeiller, Manneback et divers autres échangèrent leurs observations. L'étude de cette question paraît devoir être profitable à partir des hypothèses suivantes : On admettrait que les coefficients ne varient que très peu avec le temps autour de valeurs moyennes, les déviations étant d'ailleurs distribuées irrégulièrement au hasard suivant la loi de *Gauss;* le problème serait divisé en deux, suivant que les variations du milieu sont longitudinales ou transversales par rapport au chemin parcouru, les deux hypothèses devant ensuite être combinées. Il serait du reste important pour la pratique d'examiner aussi le cas où le signal, au lieu d'être périodique, comprendrait au début une période transitoire.

Sur la seconde question nous avons entendu principalement un intéressant exposé de M. Manneback.

Le problème se pose dans la pratique soit dans les antennes directives en dents de scie, soit dans tous les autres types d'antennes unifilaires ouvertes, de nouveau employées actuellement pour les ondes courtes.

Au cours des séances publiques du 13 septembre, trois membres de la V^e Commission ont présenté des communications.

J'ai d'abord exposé une nouvelle transformation de la théorie des circuits dont j'ai fait une application à un appareil à intensité constante et phase variable permettant de vérifier une théorie bien connue due à *Helmholtz* et *Rayleigh.*

M. Le Corbeiller a indiqué l'origine des termes gyroscopiques dans les équations du téléphone et du haut-parleur et a indiqué une généralisation relative aux appareils électromécaniques monophasés oscillants ou rotatifs.

M. Salomon a indiqué l'analogie entre la rotation propre d'un gyroscope et un champ magnétique et donné des équivalences gyroscopiques des machines électriques synchrones, asynchrones et continues.

Plusieurs autres sujets d'un très grand intérêt auraient dû être exposés par certains membres qui en ont été empêchés par le temps trop court mis à notre disposition. Nous espérons que d'ici à la prochaine réunion un ensemble de travaux pourra être préparé qui mettra en relief l'ampleur et l'intérêt théorique et pratique du programme de la Ve Commission.

(*s.*) Dr BALTH. VAN DER POL

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Les propositions présentées par les diverses Commissions sont approuvées par l'Assemblée Générale. Sur la proposition du Président, des remerciements sont adressés à la General Electric C° pour son offre de mettre des appareils à la disposition de l'U. R. S. I.

M. le Président se fait ensuite l'interprète de l'Assemblée Générale pour remercier les Présidents et Membres des Commissions de l'excellent travail effectué.

Les Comités Nationaux doivent, ajoute-t-il, désigner eux-mêmes les membres des différentes Commissions. Nous ne pouvons pas constituer ces Commissions ici, tous les pays n'étant pas représentés.

Le Secrétariat Général se mettra en rapport avec les Comités Nationaux pour constituer les Commissions; il en publiera ensuite la liste complète.

Un certain nombre de Présidents de Commissions ont exprimé le désir d'être remplacés et en particulier MM. Abraham, Eccles et Vanni.

Nous vous proposons donc les nominations suivantes :

Commission I : Dr. Dye.
» II : Dr. Austin.
» III : Profr Appleton.
» IV : Profr Kennelly.
» V : Dr. van der Pol.

Ces propositions sont adoptées.

3° Fixation de la date et du lieu de la prochaine Assemblée Générale.

Profr De Donder. — M. De Bast, Directeur de l'Institut Électrotechnique Montefiore à Liége, a eu l'heureuse idée de suggérer le choix de la ville de Liége comme lieu de notre prochaine réunion en 1930.

Liége est en quelque sorte la capitale industrielle de la Belgique et, d'autre part, dans cette ville se tiendra en 1930 une Exposition internationale des industries mécaniques et autres.

M. De Bast a déjà pressenti M. le Général Ferrié à ce sujet, et je dois ajouter que le Secrétariat Général et le Comité National Belge sont enthousiastes de cette proposition.

De plus vous verrez comment la Belgique célébrera le centenaire de notre indépendance.

En 1930 également, se tiendra à Anvers une Exposition commerciale, maritime et d'art flamand; il est entendu que des excursions seront organisées pour visiter l'Exposition d'Anvers et vous permettre d'apprécier la Belgique entière et sentir battre en même temps le cœur de la Wallonnie et le cœur de la Flandre.

M. le Président. — Messieurs, la question de notre prochaine réunion se divise en deux parties. D'abord la date, M. De Donder propose 1930. Il s'agit de décider si nous désirons nous réunir tous les ans ou tous les deux ans. Nous pensons qu'un intervalle de deux ans est convenable. Personne n'a-t-il d'objection à présenter?

Dr. Rayner. — The British Committee thinks that Sessions ought not to be more frequent than once every two years.

M. le Président. — Personne ne faisant d'objection, la première proposition de M. De Donder de se réunir dans deux ans est acceptée.

Reste à décider si nous nous réunirons à Liége à l'occasion de l'Exposition.

Dr Rayner. — I did not know Profr De Donder had such an interesting proposal. After a conversation with some of our members we decided to suggest Holland for our next meeting.

Dr Van der Pol. — The Dutch National Committee would be very much honoured by receiving the U. R. S. I. in Holland in 1930. But we do not expect in 1930 in Holland such festivities as those that are to take place in Belgium. I think the question must be decided by the General Session.

M. le Président. — Nous acceptons donc l'invitation de M. le Prof^r De Donder, étant entendu que pour la réunion suivante nous donnerons la préférence à la proposition britannique de nous réunir en Hollande en 1932.

D^r Van der Pol. — As Holland is near Liege I propose to organise a trip to Holland where the U. R. S. I. might be received by the Dutch National Committee.

D^r Rayner. — I quite agree.

Prof^r De Donder. — Je remercie la délégation hollandaise de son amabilité. La Belgique a gardé maint bon souvenir de son ancienne union avec la Hollande, et le projet qu'elle présente est de nature à souligner les relations amicales et fructueuses qui existent entre nos deux pays.

4° Election du Bureau.

M. le Président. — Nous avons à procéder maintenant à l'élection du Bureau, que les statuts de l'Union obligent à se retirer. Je demande la permission de vous dire que je désire être remplacé et je propose de nommer à ma place M. le Prof^r Austin. Les Vice-Présidents sont dans le même cas et je demande à l'Assemblée Générale si elle a une proposition ou une observation à présenter à ce sujet.

Prof^r Austin. — The wish of the Executive Committee was that all the members of the Board should be reelected for a new period and that a fifth Vice Presidency should be offered to Prof^r Nagaoka. I propose that suggestion of the Executive Committee to be adopted by the General Assembly.

M. le Président. — Le Bureau tout entier, par ma voix, vous remercie profondément de l'honneur que vous lui faites en le maintenant en fonctions et il s'efforcera de mériter votre bienveillance dans l'avenir.

Le Secrétaire Général doit aussi être soumis à réélection, mais le Comité Exécutif a décidé qu'il devait rester éternellement en fonctions et propose de nommer M^r R. Goldschmidt Secrétaire Perpétuel.

M. le Secrétaire Général. — Je ne désire pas que le mot « perpétuel » me soit appliqué. Il signifie immuable, le mouvement perpétuel est en contradiction avec la science. Je désire donc être soumis à réélection chaque fois.

M. le Président. — Je vous propose donc de réélire cette fois-ci notre Secrétaire Général.

Je propose qu'il soit décidé que les Présidents des Commissions assistent aux réunions du Comité Exécutif; il est indispensable qu'ils donnent leur avis sur les différentes questions soumises à l'approbation du Comité Exécutif.

Je remercie d'abord le Comité National Belge de toutes les amabilités qu'il a eues pour nous et de toutes les attentions dont nous avons été entourés pendant notre séjour et auxquelles nous avons tous été extrêmement sensibles.

Je remercie particulièrement M. le Prof^r De Donder, qui honore son pays et la science du monde entier et qui a bien voulu nous donner beaucoup de son temps très précieux. Nous n'oublierons pas le travail remarquable qu'il a fourni ni la part qu'il a prise aux discussions auxquelles il a assisté, ainsi que tous les aperçus profonds qu'il nous a suggérés, et je suis certainement l'interprète de tous en le remerciant chaleureusement ainsi que toute la délégation belge.

Je désire aussi remercier une fois de plus notre Secrétaire Général; mais ne devons-nous pas le remercier toujours, lui dont nous avons toujours besoin, ainsi que tous ses collaborateurs du Secrétariat Général qui tous se dévouent : MM. Paul Goldschmidt et Homès ainsi que ces demoiselles.

M. le Secrétaire Général. — Je désire également que nous adressions des remerciements à M. Le Corbeillier ainsi qu'à MM. de Vaucleroy, le Capitaine Herbays et l'Ingénieur Revol pour leur collaboration.

Prof^r De Donder. — A peine cinq jours se sont écoulés depuis notre première réunion. Les travaux auxquels nous avons participé ont créé entre nos esprits et nos cœurs de nouveaux liens; pour vaincre les difficultés, nous avons vibré à l'unisson. Jamais je n'ai eu une impression de joie profonde, comme celle que j'ai ressentie pendant ce Congrès. Il y a eu vraiment une émulation splendide de la part de tous. On voyait la joie rayonner sur tous les visages quand l'un ou l'autre collègue annonçait une nouvelle vérité, une nouvelle découverte relative à ce vaste monde qui s'appelle la Radio.

Il est bien certain que cela est dû en grande partie à la façon gracieuse et toute française dont notre Président, M. le Général Ferrié, a conduit nos différentes discussions. Aussi je vous convie à pousser un hourrah en l'honneur de notre admirable Président.

Je vous remercie vivement des sentiments de sympathie que vous avez exprimés au Comité National Belge; je suis particulièrement sensible aux marques de confiance et d'amitié que vous avez bien voulu me donner.

M. le Président. — Je remercie M. le Prof^{r} De Donder pour ses très aimables paroles.

Messieurs, l'Assemblée Générale de l'U. R. S. I. se termine et je crois que nous pouvons être satisfaits de notre travail.

La séance est levée à 12 h. 40.

ANNEXES

Annexe 1. Document : 1928. A. G. 1

Propositions du Comité Français de Radiotélégraphie Scientifique pour l'organisation d'une étude d'ensemble sur les phénomènes de propagation des Ondes.

Le fait qu'il existe une relation entre l'activité solaire et la propagation des ondes est aujourd'hui très probable. Néanmoins, il semble bien que des recherches de longue durée soient encore nécessaires pour mettre en évidence d'une façon indiscutable l'existence de cette relation et par conséquent pour chercher à en déterminer les causes. Les raisons qui ont conduit le Comité Français à cette conclusion sont exposées dans une note annexe rédigée par M. Maurain, directeur de l'Institut de Physique du Globe et doyen de la Faculté des Sciences de l'Université de Paris (voir page 24).

Ces recherches de longue durée auxquelles nous venons de faire allusion doivent évidemment être conduites suivant les procédés qui ont si bien réussi aux astrophysiciens et aux géophysiciens pour mettre en évidence les corrélations qui existent entre les phénomènes solaires et certains phénomènes terrestres.

Ceux-ci ont accumulé pendant de longues années de nombreux résultats d'observations faites sans aucune prétention de discussion immédiate. Ces résultats ont été publiés intégralement et se sont trouvés ainsi au moment voulu à la disposition de tous ceux qui ont entrepris de les interpréter.

Telles sont les considérations qui ont amené le Comité Français de Radiotélégraphie Scientifique à proposer le programme de travail ci-dessous. Il demande que cette proposition soit soumise à l'examen de la Commission de propagation de l'U. R. S. I. et exprime le désir que cette Commission prenne une décision ferme soit en approuvant le projet d'organisation de travail plus ou moins amendé qui lui est présenté, soit en lui substituant tout autre programme qu'elle aurait jugé préférable, pourvu que ce programme soit établi d'une façon assez précise pour permettre aux divers Comités Nationaux d'entreprendre sa réalisation immédiate.

Le Comité Français insiste beaucoup sur ce point que, quel que soit le mode de travail adopté, il ne pourrait être fructueux que s'il s'inspire des idées énoncées ci-dessus.

1^re^ proposition. — Ondes longues. — Une station de mesures par État adhérent à l'U. R. S. I. effectuerait quatre fois par jour, à des heures fixées, des mesures de champ en utilisant le trafic commercial des postes relativement voisins et de postes transatlantiques.

Comme postes européens, le Comité Français propose ceux de Bordeaux, Leafield et Nauen. Il demande au Comité des État-Unis d'indiquer les postes américains sur lesquels il conviendrait d'exécuter des mesures.

Il propose que ces mesures soient effectuées à 0, 6, 11, 18 et 23 heures Greenwich.

La justification de ce choix d'heures sera donnée plus loin.

2^e^ proposition. — Ondes courtes. — Dans la mesure où l'état actuel de la technique le permet, des mesures ou tout au moins des appréciations de la mesure du champ seraient faites sur des émissions d'ondes courtes dans une station de mesure par État adhérent à l'U. R. S. I.

Il propose que les stations de mesure européennes effectuent leurs opérations sur les signaux horaires émis à 3 heures et 17 heures Greenwich, sur trois fréquences différentes, pour le poste d'Arlington et sur le bulletin météorologique émis sur les mêmes fréquences par le même poste.

Il demande au Comité Hollandais s'il ne serait pas possible de faire émettre des signaux spéciaux à l'usage des stations de mesures américaines, par le poste hollandais de radio-diffusion sur ondes courtes.

3e proposition. — Les résultats de toutes ces mesures seraient communiqués mensuellement au Secrétariat Général de l'Union dans les mêmes conditions où le sont actuellement les résultats des mesures effectués en France, à Meudon et aux États-Unis par le laboratoire de radiotélégraphie du Bureau of Standards.

4e proposition. — Le Secrétariat Général serait invité à examiner les conditions dans lesquelles pourrait être assurée la publication de ces résultats en tenant compte de ce fait que cette publication doit atteindre non seulement les radiotélégraphistes, mais tous les physiciens s'occupant de l'étude des relations entre les phénomènes solaires et terrestres.

Remarque. — Il a été prévu seulement une station de mesures par État. Il est certain qu'étant donné le développement du territoire des États-Unis, un plus grand nombre de stations serait nécessaire.

JUSTIFICATION DES PROPOSITIONS.

1re proposition. — Choix des heures. — Il était impossible d'envisager une étude continue et automatique des phénomènes de propagation, comme cela se fait pour d'autres phénomènes, par exemple, pour le magnétisme terrestre, pour l'étude duquel des enregistrements continus sont effectués dans certains observatoires. D'autre part, on s'est rendu compte que l'exécution de mesures trop fréquentes entraînerait des difficultés matérielles qui les rendraient irréalisables.

C'est ce qui a conduit à limiter à quatre les périodes journalières de mesures.

Les heures indiquées ont été choisies par ce fait que dans chaque pays, par suite des variations des saisons, un certain nombre de mesures se trouveront exécutées tantôt avant, tantôt après le lever ou le coucher du soleil.

2e proposition. — Il a semblé au Comité Français qu'il n'était pas possible d'exécuter des mesures sur le trafic commercial des postes à ondes courtes, soit à cause de l'irrégularité des transmissions, soit parce que ceux-ci sont souvent amenés à modifier inopinément leur longueur d'onde pour mieux assurer leurs communications.

D'autre part, ces postes sont souvent munis de dispositifs réflecteurs qui peuvent modifier les phénomènes de propagation.

Il est bien entendu que le programme d'études générales proposé par le Comité Français est absolument indépendant des études spéciales que poursuivent certains expérimentateurs : mesure de la hauteur apparente de la couche Heaviside, recherches sur la polarisation des ondes, etc.

Le Comité Français estime que ces études sont du plus haut intérêt, qu'il y a lieu d'adresser des félicitations à ceux qui les ont entreprises et exprime son désir de voir un nombre plus grand d'expérimentateurs s'attaquer à ces questions.

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Note sur la recherche de relations entre la propagation des ondes électromagnétiques et d'autres phénomènes terrestres ou solaires.

par M. C. MAURAIN,
de l'Université de Paris,
Directeur de l'Institut de Physique du Globe.

Les particularités extrêmement curieuses de la propagation des ondes électromagnétiques ont provoqué de nombreuses recherches. En particulier, on a cherché à établir des relations entre ces particularités et d'autres phénomènes, tels que le magnétisme terrestre, l'électricité atmosphérique, la météorologie et l'activité solaire. Ces derniers travaux sont très intéressants parce qu'on peut en attendre des indications sur les causes des particularités de la propagation des ondes électromagnétiques.

Pour étudier des relations de ce genre, deux méthodes se présentent en principe : l'une consiste à noter des coïncidences entre les particularités remarquables des deux phénomènes à comparer, l'autre à faire des études statistiques portant sur un intervalle de temps aussi grand que possible, de manière à éliminer l'irrégularité des deux phénomènes. Dans cette dernière méthode, on doit prendre pour chaque phénomène toutes les observations de même genre, à moins qu'on n'ait des raisons plausibles d'écarter une ou plusieurs catégories bien déterminées, ou de les séparer des autres.

La méthode des coïncidences nécessite une critique serrée; en effet, deux phénomènes quelconques présentant l'un et l'autre des irrégularités continuelles (comme c'est le cas pour ceux qui ont été indiqués ci-dessus) peuvent donner lieu fortuitement à des coïncidences, même s'ils n'ont aucun lien entre eux; par exemple, des maximums se présenteront en même temps, ou des variations rapides, etc. Il faut des coïncidences bien circonstanciées et nombreuses pour qu'on puisse conclure à une relation entre les deux phénomènes. Inversement, deux phénomènes peuvent être en relation sans que des coïncidences apparaissent bien nettement entre leurs particularités.

Considérons, par exemple, les perturbations magnétiques et l'activité solaire. Une étude statistique portant sur un grand nombre d'années manifeste une relation très nette entre l'agitation magnétique et l'activité des taches solaires; les perturbations magnétiques sont plus nombreuses aux époques de maximum d'activité des taches qu'aux époques de minimum. Mais si l'on cherche dans le détail une correspondance entre les taches et les perturbations, le résultat est très souvent peu satisfaisant. Il y a fréquemment des taches solaires non accompagnées de perturbations magnétiques, et inversement des perturbations magnétiques en l'absence de taches. Dans une étude portant sur quarante et une années d'observations ([1]), j'ai noté un grand nombre de perturbations magnétiques qui se sont produites, alors qu'il n'y avait eu sur le soleil aucune tache, non seulement le jour de la perturbation magnétique, mais aussi plusieurs jours auparavant et plusieurs jours après. En somme, le caractère de la relation existant entre les taches solaires et les perturbations magnétiques n'apparaît que dans une étude statistique portant sur un nombre d'années assez grand par rapport à la période des taches solaires, qui est d'un peu plus de onze ans.

Prenons un autre exemple : Le champ électrique de l'atmosphère présente des variations continuelles, souvent de très grande amplitude, avec parfois changement de signe. Je ne crois pas qu'on ait signalé de coïncidences entre les perturbations de ce champ électrique des taches solaires. Mais L.-A. Bauer a déduit en 1924 d'une étude statistique portant sur diverses séries de mesures du champ, séries encore peu nombreuses et peu étendues, que la moyenne annuelle du champ est plus grande aux époques de maximum d'activité des taches qu'aux périodes de minimum (d'environ 20 %), et les quelques années d'observations nouvelles qu'on a depuis semblent confirmer cette conclusion. On a là, l'exemple d'un phénomène dont la variabilité est très grande et due probablement à des causes très diverses (en particulier aux circonstances météorologiques locales) et où seule une étude statistique assez prolongée a manifesté une relation avec les taches solaires.

Or, les particularités de la propagation des ondes électromagnétiques se présentent comme extrêmement variables. On constate dans la direction apparente et dans l'intensité de la réception des variations continuelles, dans lesquelles les circonstances locales jouent un certain rôle. De plus, les phénomènes sont très différents pour les ondes de longueurs différentes. Il semble donc que, dans la recherche des relations entre les particularités et d'autres phénomènes, il convient de procéder avec méthode et de faire des études statistiques portant sur de longues périodes. Recevant en une station des ondes de longueur d'onde déterminée, on devra utiliser des observations prolongées d'un genre bien défini, d'intensité par exemple, et en déduire la variation diurne moyenne, la variation annuelle et la variation de la moyenne annuelle au cours des années successives. Il faut s'attendre à ne bien connaître les variations annuelles que si l'on dispose de plusieurs années d'observations, et à ne bien connaître la relation avec l'activité solaire qu'après un cycle de onze ans, et même après plusieurs cycles.

Il se présente d'ailleurs dans l'étude de la propagation des ondes électromagnétiques une circonstance assez défavorable par rapport à celles qui existent généralement. La plupart des éléments naturels, température, pression, vent, champ électrique, éléments magnétiques, etc., sont enregistrés de manière constante; on a ainsi tous les matériaux nécessaires pour une étude statistique numérique. Au contraire, les émissions d'ondes électromagnétiques utilisées sont généralement limitées à des durées périodiques courtes et peu fréquentes. Il serait désirable de disposer d'émissions constantes et d'appareils récepteurs enregistreurs avec propriétés sélectives. Des organisations de ce genre seraient précieuses pour l'étude de la propagation des ondes électromagnétiques, et elles seront sans doute nécessaires pour une application pratique de ces ondes à l'étude constante de l'atmosphère, application dont on peut espérer dans l'avenir un grand développement.

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[1] *Annales de l'Institut de Physique du Globe*, t. V, 1927, pp. 86-109.

ANNEXE 2. Document : 1928. A. G. 2.

Propositions du Comité Français de Radiotélégraphie Scientifique relativement à l'étude des Atmosphériques.

1re proposition. — Les stations travaillant sous les auspices de l'U. R. S. I. et assurant d'une manière régulière la mesure ou même l'observation des atmosphériques devront le faire à des heures déterminées du temps local.

Le Comité Français propose pour ces heures d'observation 9, 15 et 23 heures du temps local. Pour l'Europe centrale et l'Europe occidentale, par exemple, on pourrait adopter 9, 15 et 23 heures du temps moyen de Greenwich.

On demande, en outre, que dans le monde entier des observations soient faites en tous cas à 23 heures Greenwich.

2e proposition. — Le Comité Français demande que chaque pays étudie le moyen de réaliser dans une station au moins la mesure absolue de l'activité des atmosphériques (¹).

Les mesures devraient être effectuées avec un dispositif récepteur muni de filtres tels que la bande de fréquence susceptible de l'actionner ait une largeur correspondant à 500 cycles par seconde.

Au cas où la pratique obligerait à choisir une autre largeur pour la bande de fréquence, la valeur mesurée serait ramenée à la bande de 500 cycles par seconde. Il serait toutefois nécessaire de s'assurer par des expériences préalables que l'énergie recueillie à travers les filtres et provenant des atmosphériques est bien proportionnelle à la largeur de la bande de fréquence à travers laquelle on les reçoit.

3e proposition. — Il serait désirable que chaque pays, outre la station spécialement équipée pour la mesure absolue de l'activité des atmosphériques, assure un enregistrement continu qualitatif de l'activité des atmosphériques dans un certain nombre de stations (1 par 100 000 km^2). Cet enregistrement pourrait encore se faire en utilisant la méthode de Curtiss. Mais il nécessiterait des installations moins dispendieuses que la mesure en valeur absolue de l'activité.

Pour compléter ces enregistrements, on pourrait utiliser dans chaque pays un certain nombre de postes récepteurs assurant un trafic régulier en leur demandant de noter heure par heure l'intensité et la fréquence des atmosphériques. On pourrait ainsi tracer pour chacun d'eux et pour tous les jours de l'année des courbes qui permettraient de déterminer approximativement la variation diurne. Ces courbes pourraient être complétées par des indications relatives aux gênes causées au trafic par les atmosphériques.

4e proposition. — Les mesures et enregistrements seraient faits aux environs des fréquences suivantes : 130, 65 et 20 kilocycles par seconde pour les ondes longues, 4 000 et 12 000 Kc/S pour les ondes courtes.

Dans le cas où il ne serait possible d'assurer l'étude (mesures et enregistrements) des atmosphériques que sur une seule fréquence, les ob-

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(¹) Cette activité pourrait être définie comme il suit : Le courant produit par les atmosphériques dans l'appareil récepteur serait rectifié et chargerait un condensateur shunté par une résistance (méthode de Curtiss). On évaluerait le courant traversant cette résistance. On réaliserait ensuite le même courant en faisant agir sur le dispositif récepteur un émetteur auxiliaire. Le champ produit par l'émetteur à l'endroit où se trouve le récepteur (évalué en microvolts par mètre) serait considéré comme égal au champ moyen produit par les atmosphériques.

servations seraient faites uniquement sur la fréquence de 130 Kc/S. De même s'il n'était possible d'assurer des mesures absolues que sur une seule fréquence, ces mesures absolues seraient aussi effectuées sur la fréquence de 130 Kc/S, et s'il n'était possible de les assurer que sur deux fréquences, on choisirait 130 Kc/S et 12 000 Kc/S.

5e proposition. — Le Comité Français propose qu'en vue d'apporter des documents nouveaux sur la portée des atmosphériques, il soit recommandé de diriger d'une façon générale les observations de telle manière qu'elles aboutissent à des tracés sur carte, même rudimentaires, de courbes d'égale intensité des atmosphériques et au tracé de cartes d'isochrones des variations rapides et importantes de l'activité des atmosphériques.

JUSTIFICATION DES PROPOSITIONS CI-DESSUS.

1re proposition. — L'heure locale à laquelle est faite l'observation des atmosphériques n'est pas indifférente; les heures que nous avons choisies dans notre proposition sont destinées à mettre en évidence chacune des trois catégories d'atmosphériques auxquelles on aboutit quand on classe ceux-ci d'après leur variation diurne.

A 9 heures, l'influence des atmosphériques nocturnes a toujours disparu, mais celle des atmosphériques d'après-midi (atmosphériques stagnants) ne s'est pas encore fait sentir. Une observation faite à 9 heures mettra presque uniquement en évidence les atmosphériques migrateurs.

15 heures est l'heure du maximum des atmosphériques stagnants : une observation faite à ce moment les mettra donc en évidence.

L'observation de 23 heures mettra en évidence les atmosphériques nocturnes.

Il n'y a pas d'inconvénient à adopter les heures du temps moyen de Greenwich pour l'Europe occidentale et pour l'Europe centrale. Par contre, sous les autres méridiens il faudra choisir des heures voisines de 9, 15 et 23 heures du temps local (et qui pourront en principe être les mêmes sur 30 degrés de longitude).

Enfin, une observation assurée dans le monde entier à 23 heures, temps moyen de Greenwich, fournira des renseignements utiles pour l'étude de la portée des atmosphériques nocturnes.

2e proposition. — La mesure en valeur absolue de l'activité des atmosphériques nécessite un appareillage beaucoup trop onéreux et beaucoup trop complexe pour qu'on puisse la demander à un grand nombre de stations.

Aussi doit-on se contenter d'un nombre restreint de ces mesures; d'autre part, la question de la mesure des atmosphériques est plus complexe que la question de mesure d'un champ, puisque, d'une part, il faut adopter une définition plus ou moins arbitraire pour définir ce qu'on entend par le champ provoqué par les atmosphériques et, d'autre part, il faut tenir compte également de la largeur de la bande sur laquelle on reçoit.

3e proposition. — L'enregistrement continu ne laisse échapper aucun phénomène même passager. Il permet la comparaison avec les phénomènes météorologiques et il permet d'appliquer aux atmosphériques la méthode d'analyse détaillée de cas particuliers (diagnose) qui est à la base de toutes les études météorologiques modernes. Enfin l'enregistrement continu nous donne immédiatement des renseignements sur la variation diurne (¹).

Bien que très rudimentaire, la méthode qui consiste à demander à un poste récepteur assurant un trafic régulier de tracer directement des courbes de variation des atmosphériques est susceptible de fournir une première approximation.

En effet, il ne faut pas oublier que la variabilité du phénomène est telle qu'elle dépasse souvent de beaucoup les variations que peuvent introduire dans les observations les instruments et les observateurs.

La méthode directe pourra déjà nous renseigner sur les périodes d'atmosphériques violents, sur les instants où elles commencent et où elles finissent; ce sera déjà un point très important.

4e proposition. — Bien que les propriétés de la résonance influent fortement sur la quantité

(¹) Ici, il suffira d'avoir des appareils dont on peut vérifier et maintenir la constance. Ils fourniront donc seulement des valeurs relatives. Ils pourront donc être moins onéreux à établir que les appareils de mesure en valeur absolue.

d'électricité formée par les atmosphériques, il est certain que les atmosphériques présentent déjà par eux-mêmes des variations le long de la gamme des fréquences, c'est pourquoi nous proposons que les mesures soient toutes faites, autant que possible, sur les mêmes fréquences et que l'on choisisse trois fréquences basses, deux fréquences élevées.

Il arrivera souvent que, pour des raisons d'économie, on ne pourra assurer à la fois les mesures sur les cinq fréquences proposées. Il en sera à fortiori de même pour les enregistrements. Il importe que toutes les stations qui ne travaillent que sur une fréquence travaillent toutes sur la même. C'est pourquoi une fréquence à choisir de préférence est indiquée dans les ondes longues et une autre dans les ondes courtes.

5e proposition. — Il importe d'arriver à séparer dans l'action totale observée l'action des atmosphériques lointains de celle des atmosphériques locaux.

Il est évident, en effet, que si la grande majorité des atmosphériques, à un moment donné, émane d'un centre lointain, les courbes d'égale activité seront disposées concentriquement autour du point d'origine. Ce point devra être tout aussi bien révélé par ces courbes que par les expériences radiogoniométriques.

D'autre part, si la cause des modifications rapides observées dans la variation diurne est une cause lointaine (plusieurs milliers de kilomètres), les heures où sont observées ces modifications rapides pourront être les mêmes dans toutes les régions affectées par cette cause lointaine.

ANNEXE 3.

International programme of observations on atmospherics.

In the course of a full discussion on the present position of research on atmospherics, Captain R. Bureau, France, and Mr. R. A. Watson Watt, Great Britain, agreed that it would be of value to draft, for presentation to their respective National Committees, a programme for international observations which they could both support, in the hope that the two National Committees could also support the proposals at the meeting of the International Union. The draft proposals are as undernoted, viz :

a) Atmospheric observations to be made at fixed hours daily, these hours being 9, 15 and 23 G. M. T. for Western and Central Europe, 9, 15 and 23 Zone time for the rest of the world, and 23 G. M. T. for the whole world.

b) Records of absolute equivalent field strength on one specified wave band to be made continuously at one station per country by a method using the Curtiss integrating circuit.

c) That an international classification of atmospherics be attempted, and that the nature of the individual atmospheric in each category should be investigated by oscillographic means.

d) That organised experiments on effective range should be arranged and that the following alternative methods should be considered.

1. Drawing of isoparasitic curves for selected occasions.
2. Determination of isochrones of incidence or disappearance of special types, as, for example, of the characteristic night atmospherics.
3. Radio goniometric methods.
4. Use of broadcast matter as time base.
5. That the relation of atmospheric disturbance with other geophysical phenomena should be discussed.

While both parties agree to the programme thus expressed in general terms, it is clear that a detailed specification is necessary before the programme can be carried out, and that disagreement on details is not improbable. The following specification is suggested as likely to represent the British point of view, viz :

a) The nature of the observations to be made at the « fixed hours » must be specified. It is proposed that these should be of the type referred to as Q. 1, Q. 2, and Q. 3 in the British programme discussed at Washington. The observations of type Q. 1 A could only be made at these hours if an *ad hoc* broadcast transmitter

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(¹) Cf. DE BELLESCIZE, *Onde électrique*, novembre et décembre 1927.

were available; this might be attainable in the case of short waves.

b) It is suggested that the most strictly quantitative circuit conveniently applicable is the narrow-band recorder designed at the Radio Research Station, and that a 25-cycle band centred at 14 kc. would be found suitable for this proposal.

c) No suggestions for classification are offered, but attention is called to the classification of wave forms adopted at the Radio Research Station.

1. The only acceptable basis for this proposal would appear to be the use of records from (*b*).

2. Captain Bureau relies on aural observation for this type of material; British Observers do not favour aural criteria of intensity. Method (*b*) is again desirable.

3. Methods P. and Q. 3 of the British programme are appropriate here.

4. Method Q. 1 A has proved itself valuable, and in particular German workers attach great value to its further application.

5. No detailed proposals need be offered here; the section throws open the whole field of atmospherics research to discussion.

* * *

Bruxelles. — Imp. Hayez, rue de Louvain, 112.

Mai / May 1929 VOL. II Fascicule 3

Union Radio Scientifique Internationale

International Scientific Radio Union

PALAIS DES ACADÉMIES, BRUXELLES

Secrétariat Général : 54, avenue des Arts, Bruxelles

Recueil des Travaux de l'Assemblée Générale tenue à Bruxelles en Septembre 1928

Papers of the General Assembly held in Brussels in September 1928

COMPTES RENDUS DES SÉANCES DES COMMISSIONS

MINUTES OF THE MEETINGS OF THE COMMISSIONS

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INTRODUCTION

La Commission des *Méthodes de Mesures et Étalonnages*, la Commission de *Propagation des Ondes*, la Commission des *Perturbations Atmosphériques* et la Commission de *Liaison avec les Opérateurs, Praticiens et Amateurs* furent instituées par décision de l'Assemblée générale de l'U. R. S. I. tenue à Bruxelles en juillet 1922.

L'activité de ces Commissions depuis l'Assemblée Générale de 1922 jusqu'à l'Assemblée Générale tenue à Washington en octobre 1927 est résumé dans les fascicules 2 à 6 du volume I de l'U. R. S. I.

La Commission de *Radiophysique* fut instituée par décision de l'Assemblée Générale de Washington sous le nom de Commission des *Oscillations*, dénomination qui fut changée lors de la dernière Assemblée Générale.

Les travaux exécutés par les différents Comités Nationaux de l'U. R. S. I. depuis l'Assemblée Générale de 1927 ont été résumés et discutés, et des programmes de travaux ont été élaborés au cours de l'Assemblée Générale de l'U. R. S. I. tenue à Bruxelles en septembre 1928.

The Commission of *Measurements and Standardization*, the Commission on *Radio Wave Propagation*, the Commission of *Atmospherics* and the Commission of *Cooperation with the Amateurs* have been instituted by the decision of the General Assembly of the U. R. S. I. held in Brussels in July 1922.

The activity of these Commissions from the General Assembly of 1922 until the General Assembly held in Washington in October 1927 is summarized in the fascicules 2 to 6 of volume I of the U. R. S. I.

The Commission of *Radiophysic* has been instituted by the decision of the General Assembly held in Washington under the name of Commission of *Oscillations*, that denomination was changed during the last General Assembly.

The works made by the different National Committees of the U. R. S. I. since the General Assembly held in 1927 have been summarized and discussed, and programs of works have been elaborated during the General Assembly of the U. R. S. I. held in Brussels in September 1928.

Travaux de la Commission de Mesures et Etalonnages.

Papers of the Commission of Measurements and Standardizations.

La Commission des Méthodes de Mesures d'Étalonnages qui a siégé à Bruxelles en 1928 était composée des savants suivants :

The Commission of Measurements and Standardization which was held in Brussels in 1928 was composed of the following savants :

Angleterre : Dr. D. W. DYE, F. R. S., du National Physical Laboratory.
Belgique : M. R. CORTEIL, Ingénieur Principal de l'Administration des Télégraphes.
États-Unis : Dr. L. M. HULL, des Radio Frequency Laboratories Inc. Boston.
France : M. R. MESNY, Professeur Principal d'Hydrographie, Professeur à l'École Supérieure d'Electricité.
Italie : Prof. G. VANNI, Directeur de l'Institut Central Militaire de Radiotélégraphie.
Japon : Prof. H. NAGAOKA, Professeur à l'Université de Tokyo.
Pays-Bas : Dr BALTH. VAN DER POL, du Natuurkundig Laboratorium der N. V. Philip's Gloeilampenfabrieken.

Les séances de la Commission étaient présidées par M. D. W. Dye.

The meetings of the Commission were presided at by Mr. D. W. Dye.

Séance du Mercredi 12 Septembre 1928

Meeting of Wednesday September 12, 1928

La séance est ouverte à 9 h. 30.

M. le Président. — I regret that I am unable to present a general report on the present status of wireless standards and measurements, since no reports have been received from the various National Committees except that drawn up on behalf of the British National Committee. Copies of this have been circulated and are before the members of this assembly (1).

There are also no proposals for consideration, so that under circumstances, the simplest plan will be to use the general framework of the simple British report and to fill in the information which will be forthcoming from the various delegates on Commission I. We can also use the fascicule n° 3 of the Papers of the General Assembly held in Washington last year. This is practically a verbatim report of the meetings of Commission I held in Washington last year.

The matter falling within the scope of the Commission can be considered under three headings :

1. Frequency.
2. Current and Electromotive Force.
3. Measurements and Properties of Circuits.

In connection with the discussions under these headings, it will prevent too much digression if attention is directed rather towards the international aspect of the subjects than to the local or personnal aspect of them.

Considering therefore frequency first, we are already in very general agreement that our standards are derived as directly as possible from the unit of time and that the best means of satisfying ourselves internationally as to the accuracy with which the stepping upwards or downwards between the clock and the radio frequency is actually done, is by measurements in different countries of one or more sources of radio frequency which are unvariable as possible.

There are two ways by which we may do this :

1. By approximately simultaneous measurements of the frequencies of waves received from transmitting stations of sufficiently constant frequency.
2. By the measurement in different countries of the frequencies of portable sources of radio frequencies of a sufficiently perfect kind.

I think we should devote considerable discussion to these two means at our disposal and to any other means which may suggest themselves and I think also that we should consider carefully the possibilities of organising a definite scheme, whereby the intercomparisons may proceed in a manner sufficiently automatic to ensure continuity in the comparisons as time goes on, but yet allow full use to be made of advances which will doubtless be made.

I mention this because it seems probable that we shall not have general assemblies every year but should provide for a three years programme.

Ing. Braillard. — Je désire dire quelques mots au sujet du travail pratique qui a été fait sous les auspices de l'Union Internationale de Radiophonie, et qui avait pour but de maintenir constantes les fréquences des stations émettrices européennes afin d'utiliser au mieux les bandes de fréquences réservées à la radiodiffusion. Le travail du laboratoire a consisté d'abord dans la construction et l'étalonnage d'ondemètres — que vous pourrez voir demain, lors de la visite du laboratoire — ondemètres qui ont été distribués à chacune des stations de radiodiffusion de l'Union; ces ondemètres avaient une précision de 2 à 3 dix-millièmes. La seconde partie du travail du laboratoire est le contrôle à distance de la fréquence des ondes émises par les stations fonctionnant déjà à Bruxelles, Keston (Angleterre) et Berlin, et d'autres qui sont en construction à Stockholm et à Prague. Chacune de ces

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(1) Voir annexe, p. 35.

stations possède un diapason étalonné avec une précision de 2/100.000, au National Physical Laboratory par les soins de M. Dye.

Entre Keston et Bruxelles, on a trouvé une correspondance de 1/10.000 entre les stations. Des essais semblables ont été faits par Giebe à Berlin.

On peut donc, à distance, comparer les étalons avec une précision de 1/10.000, ce qui est suffisant pour les desiderata de la pratique.

Les mesures locales des fluctuations de fréquence autour d'une valeur donnée ont pu être faites avec une précision de 1/100.000, ce qui est un très bon résultat. Il s'agit ici, bien entendu, de mesures relatives.

Nous verrons demain les installations et les graphiques relatifs à ces mesures. Des graphiques ont déjà été mis en circulation et j'espère que la plupart d'entre vous les ont vus.

M. le Président. — For national laboratory measurements it would be desirable to use frequencies as steady as possible and for that to equip commercial stations with quartz oscillators. Quite recently we have been organising some preliminary transmissions in order to find out the conditions under which they can best be received, and whether they can serve the purpose intended.

In 1927, it was arranged through the kind cooperation of Commander Hoyt-Taylor that time signals or special signals would be sent by the American Naval Station at Annapolis (N. K. F.), on short waves which might prove valuable for intercomparison purposes, since the station is crystal controlled with thermostatic regulation of the crystal temperature. Tests were made and I made myself some measurements with these signals, but at present the results are not yet sufficient to make any definite statement.

I understand that Mr. Jouaust in France has also made some observations. The accuracy of these frequency comparisons was of 1/100.000.

Members of other countries may have something to say on this matter.

In any case it is desirable that more tests should be made.

Dr. van der Pol. — With what accuracy do you hope to measure frequencies corresponding to 15 to 30 meters wave lengths?

M. le Président. — I think an accuracy of 1 part to 10^5 could be obtained assuming sufficient constancy at the transmitting station.

Ing. Braillard. — Quant à la question de la stabilité de la fréquence de l'onde, j'estime qu'il est possible d'établir une station dont la fréquence soit de l'ordre de 20 millions de cycles par seconde avec une scintillation de 50 à 60 (ou 20 à 50) cycles. Pour les stations à ondes longues (1 mégacycle par seconde) sans cristal, telles celles de la radiodiffusion, les scintillations sont de l'ordre de 1 à 2 cycles par seconde. On atteint donc une précision de 1 millionième environ, pour des mesures relatives bien entendu.

On peut donc parfaitement obtenir la précision réclamée par le D^r^ Dye.

Prof^r^ Mesny. — Si l'on considère une transmission par ondes courtes, sur de longues distances, il y a une autre cause d'erreur provenant des variations de la longueur du chemin parcouru par l'onde, ou des variations des milieux qu'elle traverse.

Dr. van der Pol. — It is a manifestation of the Doppler effect.

Prof^r^ Mesny. — En effet, si l'on envoie, par exemple, une onde de 20 m. d'Europe aux États-Unis, le trajet comporte environ 300,000 longueurs d'onde.

Une variation de 1/100 dans le chemin parcouru correspond à 3,000 longueurs d'onde et si cette variation se produit en dix secondes elle donnera lieu pendant ce temps à une variation de fréquence de 300 cycles par seconde.

Général Ferrié. — Il faut être prudent lorsqu'on parle d'effet Doppler. Ne s'agit-il pas de l'effet Compton? En réalité, nous constatons des variations mais nous ne sommes pas très sûrs s'il s'agit de tel ou tel effet.

M. le Président. — These effects increase the importance of the measurements and forme a further reason for undertaking them.

Profr Vanni. — Étant donnée l'importance de toutes ces remarques, je pense qu'il serait désirable d'organiser en Europe une émission sur une longueur d'onde de l'ordre de celle signalée par M. Mesny, de façon à pouvoir étudier les phénomènes dont il vient d'être question.

M. le Président. — It is a very good suggestion. I don't know if short wave European stations would actually have the required constancy. Perhaps a Beam station might be suitable?

May we not consider here the creation of a new station? Is there no station near Brussels of which the transmissions would have the constancy required. Could the laboratory of Mr. Braillard help us?

Ing. Braillard. — Notre laboratoire ne possède pas de station d'émission; mais certaines stations Beam ont une stabilité de 50 périodes. Les futures stations Beam seront contrôlées par un cristal ou tout autre dispositif aussi bon. N'oublions pas qu'il s'agit là de stations commerciales.

Général Ferrié. — M. Braillard pourrait peut-être faire une enquête à ce sujet et indiquer à M. le Président la station qu'il aurait trouvée la meilleure à ce point de vue.

Ing. Braillard. — Je me mets bien volontiers à la disposition de la Commission pour organiser cette enquête.

M. le Président. — A program can probably be arrived at by forming a small sub-committee amongst those who are most interested in the question.

MM. Dye, Braillard, Hull, Mesny, Vanni et van der Pol sont désignés pour composer ce sous-comité.

Profr Vanni. — J'ai écouté à Rome la station de Eindhoven et j'ai observé que ses émissions sont remarquablement constantes au point de vue pratique du moins. On pourrait peut-être envisager l'emploi de cette station.

Dr. van der Pol. — At the Philips works we took great care to obtain the utmost steadiness possible. The modulation of the frequency must be reduced as much as possible. Until now, it did not seem necessary to fit the crystal controlling the station with a thermostatic regulation.

Dr. Appleton. — In connection with the Doppler effect which has been mentioned, I think that the notion of the Kennelly-Heaviside layer would have to be very rapid to produce the frequency changes that have been mentioned. If we consider a vertical notion of the layer, a velocity upwards or downwards of 90 kilometers per minute would be required to cause a variation of 1 part in 10^5 in the received frequency, if a wave-length of 100 metres is used.

If we consider a notion of the layer in the direction of propagation the phenomena would be similar to that investigated by Fizeau and we should expect merely an alteration of phase and not an alteration of frequency. The medium would have to be accelerated in the direction of motion for the frequency to be altered.

Profr Mesny. — Dans mon idée, il s'agissait simplement des variations momentanées du chemin parcouru. S'il y a des variations de la longueur du chemin, on doit observer des variations momentanées de la fréquence.

Cela a été mis en évidence, notamment par Rukop, au cours d'essais de téléphotographie entre Nauen et Rome, sur une distance de 1,100 kilomètres, les variations de la longueur du chemin atteignirent 300 kilomètres et produisirent des variations de fréquence allant jusqu'à 1,000 cycles par seconde.

Dr. van der Pol. — I used the term « Doppler effect » in the most general meaning.

A similar effect is observed when the ray between two stations is reflected upon a moving mirror.

One may speak of a generalised Doppler effect when the propagating medium is submitted to slight variations.

Dr. Appleton. — Yes. The same thing is observed in acoustics. The wind produces a similar effect.

M. Mesny. — Il s'agit d'un phénomène transitoire.

M. le Président. — These variations in the received frequency do doubtless exist in rela-

tion to the transmitted frequency, but I think they may be neglected from the point of view of international comparisons.

The variations of transmitting frequency are very important from the point of view of comparisons which are not simultaneous.

Dr. van der Pol. — I think that the frequency variations at the receiving end are probably of the same order as the frequency of the fading.

Prof^r^ De Donder. — Permettez-moi de rappeler que l'effet Doppler bien connu en optique n'a été traité mathématiquement que dans le cas du mouvement relatif rectiligne et uniforme. Or il s'agit ici n'est-ce pas, de mouvements absolument généraux. Le problème relève de la dynamique de la relativité générale; l'étude de ce problème est encore très peu développée.

N'oublions pas que dans le cas dont il est question nous avons affaire à une très forte généralisation de l'effet Doppler.

Dr. van der Pol. — I think this question rather belongs to the work of Commission II and perhaps also of Commission V.

M. le Président. — I should like to draw your attention to the second means of comparison measurement which I have already mentioned, I mean the circulation of a piezo-electric quartz crystal oscillator round the laboraties. We ought to be grateful towards the American members who put the crystal oscillator already measured into circulation. I suggest that perhaps the Americans might continue to circulate the oscillator already used for the purpose.

Dr. Hull. — I will state that we should be very glad at the « General Radio Company » to furnish a temperature-controlled piezo-oscillator which could be allocated to the use of the U. R. S. I. That portable apparatus could be circulated amongst the various members who are interested and who have the facilities of making the measurements.

I would suggest in that connection that I personally and my associates will not be able to carry out the measurements in Europe, but it may be well that someone of the members of the sub-committee takes the responsability for making the measurements in Europe and sending the oscillator back to U. S. which would allow us to make further comparisons of our standards.

Prof. Nagaoka. — It should be desirable, at least for remote countries like Japan, to receive a separate standard, owing to the risks of damage during transport.

Dr. Hull. — I wish to state personally that I am not in favor of circulating such apparatus in various countries particularly if it is impossible to make a personally conducted tour. I believe that the results so obtained are more likely to be deceptive but if the Committee decides that such a plan should be carried out we should be very glad to cooperate with the material.

Général Ferrié. — Diverses circonstances rendent très difficile l'envoi d'un physicien dans les différents laboratoires. Mais il serait désirable, à mon avis, d'envoyer plusieurs appareils périodiquement. Ces appareils circuleraient en se suivant à intervalle de trois ou six mois, par exemple. La répétition des comparaisons donnerait plus de sécurité.

Cela a déjà été fait et a donné d'excellents résultats, mais, j'insiste, il faudrait plusieurs appareils dont les envois seraient décalés régulièrement.

M. le Président. — I quite agree with General Ferrié.

Prof^r^ Vanni. — Il serait bon de s'entendre sur le choix d'une méthode de comparaison. Fixons une telle méthode, variable évidemment suivant l'ordre de grandeur des longeurs d'onde.

Ing. Braillard. — Permettez-moi d'appuyer la proposition de M. Vanni et de demander qu'on n'envoie pas seulement le cristal, mais bien tout le montage, cristal et accessoires. Le cristal devra être taillé pour une fréquence aussi basse que possible, de l'ordre de 100,000 à 150,000 pour avoir une haute précision dans l'étalonnage. Je parle par expérience, ayant utilisé un cristal pour une onde de 2,000 mètres.

Prof^r^ Mesny. — C'est dans ces conditions que l'appareil à cristal du Bureau of Standards circulait l'année dernière. Il a conduit à une bonne précision.

Général Ferrié. — Il conviendrait d'examiner la question au point de vue financier : il serait sans doute trop coûteux de se procurer et d'envoyer les appareils, mais nous pourrions envisager la question ultérieurement quand la situation budgétaire sera meilleure.

M. le Président. — I think that we shall arrive at a satisfactory arrangement in entrusting the question to the sub-committee. It seems to me unnecessary to have a number of oscillators, two would be enough if the circulation takes six months.

It is proposed to hold a meeting of the sub-committee this same evening at 9.0 p. m.

La séance est levée à 10 h. 45. La prochaine réunion est fixée au vendredi 14 septembre 1928 à 9 heures.

Séance du Vendredi 14 Septembre 1928

Meeting of Friday September 14, 1928

La séance est ouverte à 9 h. 30.

M. le Président. — At our last meeting we discussed in detail the question of frequency and the comparison of measurements and a meeting of a small committee was held on Wednesday evening at which the following general decisions were arrived :

That we should arrange with Dr Hoyt Taylor to transmit signals from the short wave station at Arlington for the purpose of the measurements at high radio frequencies at times to suit the transmission.

It was agreed to ask him to send them early in the afternoon : 17 hours Greenwich.

We may have further experiments to make in regard to the reception in the winter because it is probable that there will only be a very short time interval which is suitable.

We did not discuss the question whether very short dots should be sent in the manner described in the paper which was read at yesterday's meeting and it would be interesting to have a word or two on that question to decide whether we should include in the same program these very sharp dots.

It was then further discussed whether we should carry out experiments on one of the lower frequency stations such as a broadcasting station; M. Braillard can inform us on this question by reason of the measurements which he has made on the steadiness of frequency on a number of such stations.

It was also considered that certain measurements could be made using special signals on a certain station and I think probably the station 5 G. B. (Daventry) will be as suitable as any other for this purpose as it seems probable that we can make arrangements in England.

We think the transmission may be a modulated one at a frequency of 999 cycles per second, the transmission being controlled by a tuning-fork of great precision calibrated in my laboratory.

I should be happy to have the Members' ideas on that matter.

Général Ferrié. — C'est une excellente idée.

M. le Président. — Perhaps Mr. Braillard himself can help to arrange with Captain Eckersley regarding this matter.

Ing. Braillard. — Je ne puis que me rallier à la proposition de M. le Président et je ne doute pas que les méthodes de laboratoire donnent de bons résultats en employant le diapason étalonné par M. Dye lui-même.

M. le Président. — I think that apparatus must be regauged every two or three years.

Ing. Braillard. — Le capitaine Eckersley a commencé l'équipement de plusieurs stations anglaises avec des diapasons de 1,000 périodes. Il est très familiarisé avec toutes ces méthodes et nous pourrons avoir confiance dans les résultats. Sa collaboration avec l'U. R. S. I. dans le but proposé pourrait être utilement envisagée.

M. le Président. — Has someone any other remark to put forward?

D^r Hull. — Does the Commission intend to consider other ranges of frequencies that the range of broadcasting?

M. le Président. — No, because we don't know if measurements could be sufficiently exact in the other ranges, for want of frequency steadiness.

Dr. Hull. — What personally interests me, are the transatlantic transmissions of Daventry and I scarcely can receive them in America.

I want to know whether a telephonie frequency modulation on a short wave station is contemplated in order to bring America into the measurements.

M. le Président. — This has not been discussed but I think it may be more convenient to use the Post Office long wave station at Rugby since this is already controlled in frequency by a tuning-fork. It is possible that modulation from this fork can be obtained by arrangement.

The third matter which was discussed was the circulation of the quartz-oscillator and it was agreed that a quartz-oscillator should be circulated. That is a good method which has already been employed but it must be extended to Japan. I think that it will meet our requirements very well and it should be possible to make a circulation about once in 6 months. I might perhaps mention that the frequency of the quartz oscillator should be between 100 and 200 kc. per second. The oscillator might thus be a duplicate copy of the oscillator which has already been circulated.

Général Ferrié. — Ne pourrait-on pas mettre deux étalons en circulation à six mois d'intervalle; cela serait nécessaire si le Japon participe aux mesures, ce qui est indispensable.

M. le Président. — I doubt whether this would be a better method than the one consisting in having a separate standard circulated between American and Japan or any other remote country. What does Prof. Nagaoka think about it?

Prof. Nagaoka. — That would be a very good idea but I fear that the Custom Office opens the parcel and breaks the apparatus. I think that the only practical solution is the following : Japan would have its own standards which would be controlled in laboratory.

M. le Président. — Indeed, Prof. Nagaoka could measure his crystals oscillators by his standards of time, as it has already been done in Japan.

Général Ferrié. — Il est possible d'éviter la douane en confiant l'appareil à la valise diplomatique, comme cela se fait en Europe.

Prof. Nagaoka. — There is still the danger of transport. An apparatus of the Bureau of Standards has already been broken in Japan during the transport.

Général Ferrié. — Ce genre d'accidents est malheureusement fréquent. Quelle est l'opinion de M. le Prof^r Nagaoka?

Prof. Nagaoka. — I agree with the sending by the diplomatic valise.

M. le Président. — I think this ends the general questions submitted to the Sub-Committee and to the Commission.

I would like to know whether this program should be set on foot as from the Secretariat General or whether you would prefer myself or any other individual to take the necessary action.

Dr. Rayner. — To begin with, it would perhaps be better that the Commission take charge of it. Messrs. Dye and Braillard could get into contact with Captain Eckersley.

Ing. P. Goldschmidt. — En tout cas, le Secrétariat Général se tient à la disposition de la Commission pour lui apporter sa collaboration.

Ing. Braillard. — Je pense que pour la première fois, il serait préférable que les techniciens entrent directement en contact. Le Secrétariat Général interviendrait après. Il s'occuperait de tenir au courant les personnes intéressées d'après une copie de la correspondance que la Commission lui fournirait.

M. le Président. — It will be done so.

I would like to make a few remarks on current and voltage measurements. I think we can practically put the two together. In radio frequencies there are quite a number of differences in measurements of current and voltage from an international standpoint. At low and moderate radio frequencies these differences are not very important from the point of signal strength measurements but at the very high frequencies uncertainties are quite large and it does seem necessary to unify the measurements of current in the different countries and I would like to know if there are any members of the Commission who have any remarks to make, relative to this matter as to what could be done to improve the position.

Général Ferrié. — Je crois que M. Mesny pourrait nous donner des indications utiles à ce sujet.

Prof^r Mesny. — M. Dye se place au point de vue des étalons de mesure pour haute fréquence et je ne pense pas qu'en ce moment nous ayons quelque chose de nouveau à signaler.

M. le Président. — I might mention that some work has been done in England by Dr. Moullin who has made some experiments on a standard ammeter for use at very high frequencies up to 20,000 kilocycles per second. This is an instrument in which all those effects due to the high frequency can be calculated exactly. Instruments have already been made by companies in England and a paper on this will be published shortly but at the moment there is no information about them except a very short abstract in « Experimental Wireless ».

I think probably that further advance in knowledge on the subject could be obtained if a comparison of the various methods now available were made. This is not a matter for international comparison, I think it is a matter for some particular country to interest itself sufficiently in to carry out and I think I can arrange for this work to be done in England. The question of the foundations on which these measurements should be based are, I think, matters of national rather than international interest.

To finish the work of Commission I, we must look at the most up to date methods of measurement of capacities, self industance and resistance.

This is a matter which concerns the various laboratories rather than this committee but I might mention that we have already initiated an interchange of capacity between Great Britain and America and if any other countries would care to be included in that I have no doubt that such comparisons could be organised.

Général Ferrié. — La question est très importante. Je voudrais faire remarquer que la Commission Internationale des Poids et Mesures à décidé de faire entrer dans les attributions du Bureau International des Poids et Mesures la conservation de l'étalon de l'ohm international, des étalons de capacité et d'inductance. Il est possible qu'il s'occupe aussi de l'étalon de fréquence. Nous devons être prêts à travailler d'accord avec cet organisme. Peut-être demandera-t-il à recevoir en dépôt des étalons.

M. le Président. — I raised the question precisely because I am going to participate as British delegate at the International Conference which will be held at Sèvres for studying the electrical standards. I could, if you think it useful, put forward the question of introduction of new standards.

Général Ferrié. — Nous ne pouvons rien proposer sans connaître les intentions de la Commission Internationale des Poids et Mesures; mais je crois que nous pourrons nous en remettre à M. Dye pour décider, au moment voulu, ce qu'il y aura lieu de faire.

M. le Président. — Is there any other remark?

Prof^r Vanni. — Nous avons rencontré en Italie des difficultés dans la mesure de certaines grandeurs se rapportant aux lampes : inductance mutuelle entre grille et plaque, self inductance, résistance intérieure, coefficient d'amplification. M. Dye a fait des mesures dans ce domaine et je pense qu'il serait intéressant de connaître l'état actuel de la question.

M. le Président. — I am sorry that I have omitted to make reference to this matter. We have at the National Physical Laboratory carried out quite considerable amount of work in connection with measurements of the internal parts of valves. We have developed a bridge of the

Schering type by which these measurements can be made. Descriptions will be sent to the Radio Research Board and copies shall be distributed in the U. R. S. I. before publication. I might mention that this bridge can be used over a range of frequencies from 100 cycles per second up to rather over 1,000 kc. per second, a ratio of 1/10.000 and we have already been able to make a considerable number of discoveries on the dielectric properties of insulating materials because it is now possible to carry out measurements throughout the whole range without any interruption of the conditions.

Dr. van der Pol. — Some researches on dielectric losses (though it was not necessary to carry them to a very high accuracy) gave results quite sufficiently accurate for practical purposes. Loss angles were measured with an ordinary current-voltage method, but over a very extended frequency range. It appeared that different insulating materials showed quite different curves for loss angle as a function of frequency but some interesting general conclusions could be obtained.

As to the measurement of very small capacities such as the effective capacity between control grid and anode in anode-shielded tubes a method was devised which enabled us to detect capacities of the order of $0^{\mathrm{mm}}01$.

M. le Président. — This question is very interesting and I would like to ask Dr. van der Pol if he could not let us know the results published. Until now, the Commission did not find useful to take an interest in this type of measurement which seems to belong rather to the electrotechnic sphere. Nevertheless, it seems now that all those who do field strength measurements ought to study it.

Général Ferrié. — MM. Dye et van der Pol pourraient envoyer une description de leurs méthodes au Secrétariat Général qui se chargerait de la faire parvenir à tous les membres.

Dr. van der Pol. — I would be very pleased to do it.

M. le Président. — I have also already proposed it for the methods in use at N. P. L.

Dr. Van der Pol. — Perhaps some methods used for measuring the internal capacities of triodes of the order of a few centimetres may be of interest. We measure them e. g. with a Weston capacity-meter where it is only necessary to press a button. If the capacity of one triode is too small, we simply put ten triodes in parallel and devide by ten, thus finding a good average.

M. le Président. — Every member of the Commission might make inquiries upon the methods used in the various laboratories and give us a report. Very interesting methods are used, particularly at the Bureau of Standards, at the Bell Telephone Laboratories, etc.

Dr. Hull. — The Standards Committee of the American Institute of Radio Engineers has drawn up and published this year a general report in which a brief account is given of two useful methods for measuring the capacities of valves and also their variations with the frequency in cases where such variations are important. I do not know whether this report has not been sent to the Secretary of the Union.

M. le Président. — I second this very interesting proposal and I think that a copy of this document ought to be sent to every member. When we publish a personal work, we should save time in sending it directly to the members who are interested in it.

An other question to be put forward concerns the respective activities of the Commissions. It has been mentioned that Commission V would take in hand the study of quartz oscillations which previously belonged to Commission I. I fear this will cause indesirable overlapping.

Dr. van der Pol. — I proposed for similar cases to hold a mixed reunion of two Commissions.

Général Ferrié. — Je pense que tous les travaux expérimentaux sont du ressort de la Commission I et tous les travaux théoriques à la Commission V.

Prof. Appleton. — I do not think desirable to separate pratice from theory in this way.

M. le Président. — I agree with the opinion of Prof. Appleton. Beside I doubt that Commission V would accept to renounce any experimental verification of theories studied by its members. The limit boundary between the Commissions does not seem well defined.

Général Ferrié. — Peut-être la Commission I pourrait-elle aborder la question complète et recourir à la Commission V quand elle le jugera utile.

M. le Président. — I think any difficulties will resolve themselves if we act on the principle that we are working hand in hand.

Dr. van der Pol. — I quite agree with the Chairman.

La séance est levée à 10 h. 30.

Travaux de la Commission de la Propagation des Ondes

Papers of the Commission on Radio Wave Propagation

La Commission de la Propagation des Ondes qui a siégé à Bruxelles, en 1928, était composée des savants suivants :

The Commission on Radio Wave Propagation which was held in Brussels in 1928 was composed of the following savants :

Angleterre : Dr. R. L. SMITH-ROSE, D. Sc.; Ph. D.; D. I. C.; A. M. I. E. E.; du National Physical Laboratory. Teddington.

Belgique : Prof. Th. DE DONDER, Membre de l'Académie Royale de Belgique, Professeur à l'Université de Bruxelles.
M. H. JANNE, Professeur à l'Université de Liége.

États-Unis : Dr. L. W. AUSTIN, du Laboratory for Special Radio Transmission Research. Bureau of Standards.

France : M. R. MESNY, Professeur principal d'hydrographie, Professeur à l'École supérieure d'Électricité.

Italie : Prof. G. VANNI, Directeur de l'Institut Central Militaire de Radiotélégraphie.

Japon : Prof. H. NAGAOKA, Professeur à l'Université de Tokyo.

Pays-Bas : D^{r} Balth. van der POL, du Natuurkundig Laboratorium der N. V. Philip's Gloeilampenfabrieken.

Les séances de la Commission étaient présidées par le Dr. L.-W. Austin.

The meetings of the Commission were presided at by Dr. L.-W. Austin.

Séance du Mercredi 12 Septembre 1928

Meeting of Wednesday, September 12, 1928

La séance est ouverte à 10 h. 45.

M. le Président. — I sent to the Secretary a synopsis of our work during last year, but unfortunately there has been some delay in receiving this report so that it has only just been circulated (1). I think it better therefore to postpone its discussion until everybody has been able to examine it.

Aside from the consideration of the work which has been done during the year, we should I think, discuss certain fundamental questions as to our methods of determination of field strength. For example, how much do we really know in regard to the accuracy of the absolute measurements wich we are making. In all these measurements we go back I believe, fundamentally to the reception on a loop. How sure are we that we know that we are correct? The reception formula is easy enough to determine theoretically, but are we to consider that this reception is perhaps modified by the presence of the earth? I think that is really an important thing to take up. It may be that our assumptions have been perfectly correct but if they are not we ought to know it. I would like therefore to put this question in the hands of a small subcommittee, perhaps three or four members, I would like to hear the nomination for such a committee.

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(1) Annexe 2.

MM. le Dr. Smith-Rose, le Prof^r Mesny, le Dr. Appleton, le Dr. van der Pol sont nommés membres d'un sous-comité pour étudier l'état de nos connaissances sur la mesure de l'intensité du champ.

M. le Président. — There is a second question in wich I am very much interested, that is, the relative advantages of continuous automatic recording of signals intensity. The continuous automatic records thus far taken indicate that on the long wave lenghts at least the sequence of changes in intensity and the angle of incidence of the downcoming wave vary so much from night to night that it will be difficult to draw any general conclusions unless continuous records covering many months can be obtained.

There are, however, some serious disadvantages and limitations connected with continuous recording. First, disturbances of various kinds may affect the record if, as will be usually the case, it is not constantly supervised. Second, unless the use of transmitting stations can be procured for long periods of time we will be obliged to make use of regular commercial transmissions in making our records and will thus be shut out from all those important lines of work involving the use of special signals.

I think it would be wise to have this question considered by a small committee so that the difficulties and advantages of the methods of carrying on observations can be brought in concrete form before the Commission. I would like nominations for such a committee.

MM. le Prof^r Appleton, le D^r Austin, le Capitaine Bureau sont nommés membres de ce sous-comité pour l'étude du contrôle des émissions et des enregistrements.

Prof^r Appleton. — I hope that the sub-committee on the recording signals will include in their programme the study of short-distance transmissions for with such cases the presence of a strong ground wave makes correlation of records an easy matter since variations of transmitter current may be allowed for.

The President agrees to admit this shall be done, it being understood however tha the work of the sub-commission must not be limited.

We have also another series of problems which I think might be advantageously put in shape by another sub-committee before they are presented to the Commission, and that is the study of the relation of field strengths and possibly some of the other phenomena of downcoming waves to other natural phenomena, especially solar conditions and the changes in the earth's magnetism. Will you make nominations of a small committee to consider these questions?

MM. le Général Ferrié, le Dr. Rayner sont proposés comme membres de ce sous-comité.

Prof^r Vanni. — Cette question est très intéressante mais relève de la IV^e Commission.

M. le Président. — If the IVth Commission organises a sub-commission to study this question, we will leave it.

On convient d'agir de la sorte.

M. le Président. — Having disposed of this question of the relations of radio reception to other phenomena, a third committee can take up some proposals of the French National Committee (¹) wich have only reached me since I

(¹) Fascicule 2, annexe 1.

came to Brussels and which I have therefore not been able to go over in detail. They seem of importance and I think it would be wise to have a third committee for the consideration of these French proposals.

MM. le Prof^r^ Mesny, le Prof^r^ Nagaoka, le Dr. Smith-Rose, le Dr. Snyder sont désignés comme membres du sous-comité pour l'examen des propositions françaises.

Prof^r^ Mesny. — Une des principales questions soulignées dans le rapport du Comité Français est le choix des quelques stations émettrices qui feraient des émissions spéciales qui devraient être observées en tous les points de la surface de la terre.

M. le Président. — I think this completes our organization of subcommittees unless some one has some other subjects which he would like to bring up for special consideration.

My idea of forming the subcommittees is that by doing a little preliminary work they can put the questions in a way that we will be able to carry on the general discussion more expeditiously.

Après un échange de vues, on fixe l'horaire des réunions des sous-comités.

La séance est levée à 11 h. 15.

Séance du Vendredi 14 Septembre 1928

Meeting of Friday, September 14, 1928

La séance est ouverte à 10 h. 45.

The President asks Prof. Appleton to present the results of the work done by the second subcommission.

Prof. Appleton reads the report (¹) of the second subcommission which had :

1° to study the opportunity of continuous recording of signals;

2° to examine the special transmissions-sets for field strengths measurement;

3° to examine the propositions of the French National Committee (²).

M. le Président. — Has any one any remarks to make?

There is another subject I propose to bring into discussion; i. e., the conditions existing in the higher atmosphere. Prof^r^ Appleton discuted this question at the public session of yesterday (³) and I should like to have the opinions of other members of the Commission upon the views of Prof^r^ Appleton.

Général Ferrié. — Cet exposé lumineux nous a ouvert l'esprit à la réalité des phénomènes signalés par M. Appleton. Les idées développées dans ce travail constituent la meilleure explication à l'heure actuelle, et je pense que nous n'avons qu'à nous incliner.

M. le Président. — I should like to hear the opinion of Prof^r^ Appleton in regard to silent zones.

Prof^r^ Appleton. — When the theory of skipped distances was first put forward it appeared to fit the facts. The explanation, in its simplest terms, was that there is a limited electronic concentration in the upper atmosphere and that the waves could only be deviated by the layer to a limited extend. Short waves would be bent through smaller angles than long waves. Thus the silent zones observed with short waves were considered as due to the absence of downcoming waves from the layer, electron-limitation preventing the large-angle bending necessary to the atmospheric waves down near the sending station.

But further work showed that signals were observed within the skipped distance and that the intensity of these signals exhibited a

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(¹) Fascicule 2, p. 15.

(²) Fascicule 2, annexe 1

(³) Fascicule 1, page 149.

diurnal variation as if they were due to the dowcoming waves. It seems to me important to find out whether waves are received from the atmosphere within this region, and experiments are being carried out for the Radio Research Board between the National Physical Laboratory ans King's College in London to find if interference phenomena can be observed when the transmitting wave-length is slowly varied. Short wave-lengths such as 30 metres are to be used.

With regard to the theory of the subject Mr. T. L. Eckerley has suggested that the increase of signal at the edge of the skipped distance is due to the lower absorption consequent of the increase of the angle of incidence. My own view is that we must regard the layer as a kind of rough surface and that within the skipped distance we get only scattered on diffusely reflected rays. As we ge out further we pass from the region of diffuse reflection to that of true reflection and get stronger signals. Such an explanation give the correct relations between skipped distance and wave length.

Dr. van der Pol. — Perhaps I may here forward some technical remarks also interesting from a scientific point of view.

Here is the first point.

Recently, a Dutch engineer who has been working in the Dutch East Indies for several years with short waves, gave a lecture for the Dutch Radio Society and he told us that he could definitly state that in the Dutch Indies he could not find any skip distances with waves down to 10 metres. What he meant of course is, that he could receive an ordinary set signals sent out from such station. He has not made any direct measurement.

The second point is the following. We have now transmitted with the short wave station P. C. J. J. in Holland for over one year and we have had thousands of observations from amateurs of the whole world. I have made a statistical review of all these reports and have come to the conclusion that a little further out in Europe the signal intensity is indeed somewhat stronger than nearby. The intensity of the signals in Spain, Italy, Russia is on an average stronger than in Belgium, France and England, but the increase in the signal strength towards the limits of Europe is not very pronounced at all.

Général Ferrié confirme ces observations. Les postes à ondes courtes installés en Afrique Equatoriale et au Soudan ont permis de constater qu'il n'y avait là aucune zone de silence : on peut recevoir partout. Il importe toutefois de constater que ces conclusions ne résultent pas d'une étude systématique.

Dr. Hull. — Although I admit that any single group of tests cannot yeld a complete answer to the problem, I wish to mention that an American, Mr. J. K. Clapp, made some tests last summer, at a distance of about 55 miles over one ground path which was retained throughout the investigation.

The wave length could be varied at intervals of one metre from 30 to 50 metres. A complete absence of propagation between the two points for some particular range of wave lengths was observed at pratically all times. The wave length for which the signals disappear over this particular path was noted at all times of day.

The experiments will be the subject of a publication of the Institute of Radio Engineers.

Capitaine Bureau. — En France, un certain nombre d'expériences ont été faites sur cette question, principalement en vue d'étudier l'époque et les limites des zones de silence. En portant ces limites sur une carte, on peut aisément s'apercevoir qu'elles varient beaucoup d'un jour à l'autre. Par exemple, dans certains cas le Nord-Ouest de la France recevait les signaux de Bordeaux sur 38 mètres de longueur d'onde, tandis que ces signaux n'étaient pas perceptibles à des distances du même ordre dans le Nord-Est du pays. D'autres jours, le Nord-Est entendait et non pas le Nord-Ouest. A quoi faut-il attribuer ces modifications dans la zone de silence, à la basse atmosphère ou aux couches ionisées? Y a-t-il un retentissement des conditions électriques de la haute atmosphère sur les phénomènes météorologiques? Ou bien les conditions météorologiques influencent-elles les phénomènes de propagation au point de provoquer directement certaines de leurs anomalies? Cette double explication possible a déjà été signalée par M. le Président lorsqu'il a relaté la liaison entre les

anomalies de la propagation à faible distance et le passage des vagues de froid.

Prof Nagaoka. — Similar tests were made last year in Japan, with waves of 15 m. and more. Silent zones extending to 150 km. were found.

But I think the scattering and diffraction of waves by buildings, trees and mountains affect the transmission; generally the topographic disturbances in the neighbourhood of the sending station must be taken into consideration.

The boundary conditions for good transmission are rather difficult to fulfill.

Dr. Rayner asks Dr. van der Pol if the antenna at Eindhoven sends a large part of its energy vertically.

Dr. van der Pol. — I must confess that we did not so far investigated the question thoroughly. The antenna is made of a single wire inclined between a roof and a post. Its length is several times the wave length.

M. Le Corbeiller. — Une des curiosités de cette antenne réside dans les résultats merveilleux obtenus avec une installation de fortune.

Prof Vanni. — A l'appui de ce qu'ont dit MM. Ferrié et van der Pol à propos des propriétés remarquables des ondes courtes, je voudrais signaler des expériences de Pession et Montefinale avec des ondes courtes. Ces auteurs ont trouvé que l'onde de 15 m. semble la meilleure pour les transmissions à longue distance : elle est spécialement peu troublée par les atmosphériques. Cette onde de 15 m. est fort employée sur les navires de guerre italiens.

Il résulte d'une observation faite par MM. Pession et Montefinale que la réception d'un poste émettant sur la longueur d'onde de 15 m. était parfaite, pendant une journée troublée, alors que la réception des postes à ondes longues était mauvaise.

M. le Président. — Is there any other remarks to be made?

M. van der Bilt. — M. Alexanderson m'a confirmé, au sujet des ondes courtes, que l'onde de 15 à 16 m. était la meilleure pour les transmissions à longue distance.

M. le Président. — Does this not depend of the time of the day?

M. van der Bilt. — Je ne m'en souviens pas.

M. Brenot. — Nous avons fait de nombreuses expériences avec des ondes de 10 à 30 mètres sur des distances de 6,000 à 12,000 km. Nous n'avons pas trouvé de propriétés particulières pour une onde particulière de 15 à 16 mètres. Cela doit dépendre de l'heure et de l'endroit.

Il faut, en général, fixer son choix entre 10 et 25 mètres suivant la nature du parcours et l'étendue du trajet éclairé par la lumière du jour.

Notez que nous n'avons pas étudié les petites distances.

Les expériences que je viens de mentionner furent faites sur des très longues distances. Entre les villes européennes, nous fûmes un peu lents à employer les petites longueurs d'onde, car nous craignions de trouver des résultats trop variables, mais la pratique ne l'a pas montré. En pratique nous avons employé depuis près de deux ans des ondes plus courtes que les relations entre des villes européennes, sans trouver de portées indirectes.

M. van der Bilt. — La même expérience fut faite en Hollande en ce qui concerne la communication avec les Indes Néerlandaises Orientales et les résultats obtenus confirment ceux de M. Brenot.

M. Snyder. — For communications with San-Francisco, we have observed that a wave of 14 meters is better during the night and a wave of 22 meters during the day. A wave of 6 meters from Buenos-Ayres is heard during the whole 24 hours, — it is not heard at all in the E.-W. direction.

M. Jensen. — We found quite opposite result in our experiments with transatlantic short wave telephony between New-York and London. In our case the wave of 22 m. seems good during the night and the waves of 14 m. and 16 m. during the day.

Prof Appleton. — There is unanimous agreement on one point : At short distances the field strength is weaker than at great distances. The

question is to be decided is whether the signal within the skipped distance is due to a ground ray or whether it comes from the upper atmosphere.

M. Snyder. — The antenna of Alexanderson radiates nearly vertically.

M. le Président. — We have not finished the considerations of the question put forward by the first subcommission. (Voir rapport de cette sous-commission) (¹).

Prof Nagaoka. — It would be very interesting to examine the transmissions during the meteoric showers (August and November) in order to study the conditions of the upper atmosphere, as the disturbances may be perceptible as grinders or clicks, though they are probably very minute.

M. le Président. — This suggestion could be taken in consideration if we decide to carry on continuous recording of observations.

M. le Général Ferrié. — La Commission IV a émis le vœu de voir répandre des bulletins géophysiques permettant d'effectuer des observations complètes pendant les orages magnétiques.

M. le Président. — This matter of special transmission for measurements, I think can be taken up with the French proposals which amount to a plan for taking simultaneous observations for certain purposes. If it is decided to make these, all we shall have to do is to decide either now, or at a later time by letter, what stations shall be used for that purpose.

Prof Mesny. — Il n'est pas seulement question dans les propositions françaises de demander à certaines stations d'émettre des signaux, mais plutôt d'obtenir que les différents pays se mettent d'accord sur l'organisation de très nombreuses mesures simultanées d'intensité du champ et de méthodes d'enregistrement.

Ceci s'applique aux grandes longueurs d'onde. On a suggéré de faire porter ces observations sur Bordeaux, mais cela n'est qu'une indication, l'idée étant qu'un grand nombre de personnes effectuent simultanément des observations.

Quand à l'écoute des ondes courtes, il n'y a aucune difficulté pour l'Europe, les signaux des stations américaines y étant parfaitement reçus. Mais il serait désirable qu'une station européenne émit régulièrement des signaux analogues destinés à être écoutés en Amérique. C'est cela que nous pourrions discuter.

Pour les ondes courtes, beaucoup de questions peuvent être étudiées grâce à des observations étendues sur de longues périodes. Il y a des variations annuelles dans la réception à une certaine heure, par exemple.

Il y a donc lieu d'avoir des observateurs répartis sur une grande étendue de la surface terrestre. Même s'ils ne font pas des mesures précises, les résultats qu'ils fourniront ne manqueront pas d'intérêt. (Influence des circonstances locales, influences des phénomènes solaires, des orages magnétiques.)

M. le Président. — I think that no one is opposed to the propositions and I suggest that the subcommission should assemble once more to take the required action.

(Voir les Résolutions dans les procès-verbaux de l'Assemblée générale) (¹).

La séance est levée à 11 h. 15.

(¹) Fascicule 2, p. 14.

(¹) Pages 14 et suivantes du fascicule 2.

Travaux de la Commission des Perturbations Atmosphériques

Papers of the Commission of Atmospherics

La Commission des Perturbations atmosphériques qui a siégé à Bruxelles, en 1928, était composée des savants suivants :

The Commission of Atmospherics which was held in Brussels, in 1928, was composed of the following savants :

Angleterre : Dr. R. A. WATSON-WATT, Superintendent of the Radio Research Station. Slough.
Belgique : Prof. PHILIPPSON, Professeur honoraire à l'Université de Bruxelles.
États-Unis : Mr N. SNYDER, du General Engineering Laboratory of the General Electric Company.
France : Capitaine R. BUREAU, de l'Office National de Météorologie.
Italie : Prof. G. VANNI, Directeur de l'Institut Central Militaire de Radiotélégraphie.
Japon : Prof. H. NAGAOKA, Professeur à l'Université de Tokyo.
Pays-Bas : Prof. C. L. van der BILT, Professeur au Laboratorium voor Natuurkunde en Electrotechniek. Delft.

Les séances de la Commission étaient présidées par M. Watson Watt.

The meetings of the Commission were presided at by Watson Watt.

Séance du Mercredi 12 Septembre 1928

Meeting of Wednesday, September 12, 1928

La séance est ouverte à 11 h. 15.

The Chairman thanks the Members who called him to the Chair and remarks that owing to his absence from the General Assembly of 1927 in Washington he may inadvertently repeat or overlook some of the work done there. In view of the very full discussions under the chairmanship of Professor Mesny at Washington he proposes to proceed at once to the definite proposals for organised observations. He calls attention to the English and French papers circulated before the Assembly (1) and proposes to take the French proposals in detail. He therefore begs Captain Bureau to be so good as to give notice of the first French proposal.

Capitaine Bureau lit : « Les stations travaillant sous les auspices de l'U. R. S. I. et assurant d'une manière régulière la mesure ou même l'observation des atmosphériques devront le faire à des heures déterminées du temps local.

» Le Comité français propose pour ces heures d'observation 9 heures, 15 heures et 23 heures du temps local. Pour l'*Europe Centrale* et l'*Europe Occidentale* par exemple, on pourrait adopter 9 heures, 15 heures et 23 heures du temps moyen de Greenwich.

» On demande, en outre, que dans le monde entier des observations soient faites en tous cas à *23 heures Greenwich* ».

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(1) Fascicule 2, annexes 2 et 3.

M. le Président. — Is there any objection to this proposal fixing the hours of observations? It will be clear that at a later stage we must specify the nature of the observations to be made at these hours.

Capitaine Bureau lit les 2ᵉ et 3ᵉ propositions françaises :

» DEUXIÈME PROPOSITION. — Le Comité français demande que chaque pays étudie le moyen de réaliser dans une station au moins la mesure absolue de l'activité des atmosphériques (¹).

» Les mesures devraient être effectuées avec un dispositif récepteur muni de filtres tels que la bande de fréquences susceptible de l'actionner ait une largeur correspondant à 500 cycles par seconde.

» Au cas où la pratique obligerait à choisir une autre largeur pour la bande de fréquence, la valeur mesurée serait ramenée à la bande de 500 cycles par seconde. Il serait toutefois nécessaire de s'assurer par des expériences préalables que l'énergie recueillie à travers les filtres et provenant des atmosphériques est bien proportionnelle à la largeur de la bande de fréquence à travers laquele on les reçoit.

» TROISIÈME PROPOSITION. — Il serait désirable que chaque pays outre la station spécialement équipée pour la mesure absolue de l'activité des atmosphériques assure un enregistrement continu qualitatif de l'activité des atmosphériques dans un certain nombre de stations (1 par 100 000 km²). Cet enregistrement pourrait encore se faire en utilisant la méthode de Curtiss, mais il nécessiterait des installations moins dispendieuses que la mesure en valeur absolue de l'activité. Pour compléter ces enregistrements, on pourrait utiliser dans chaque pays un certain nombre de postes récepteurs assurant un trafic régulier en leur demandant de noter heure par heure l'intensité et la fréquence des atmosphériques. On pourrait ainsi tracer pour chacun d'eux et pour tous les jours de l'année des courbes qui permettraient de déterminer approximativement la variation diurne. Ces courbes pourraient être complétées par des indications relatives aux gênes causées au trafic par les atmosphériques. »

The Chairman observes that the second proposition contains three portions dealing respectively with: 1th the desirability of absolute measurements; 2nd the nature of the quantity to be measured, and 3rd the method of measurement.

He desires to have the opinion of the members on these three points and in particular would ask Dr. Austin's opinion on the second point.

Dr. Austin. — I can say that I am in agreement with these proposals. The realisation of this program in the United States is unfortunately in difficulty on economic ground. I will however, ask for the cooperation of the Naval Observatory and of the Aeronautical Laboratory. I hope thus to be able to collaborate to the proposed work.

Prof Nagaoka. — Several studies in atmospherics have been made in Japan, and Professor Yokoyama has obtained important results.

Prof Appleton. — I take it that the same method of specifying the « activity » of atmospherics will be used by all observers.

M. le Président. — Yes. I regard it as essential to the succes of a programme such as this, that identical methods of measurement should be used at all participating stations. May we now vote upon the first part of the second proposition?

Dr. Dye asks for a preliminary agreement upon :

1. The quantities to measure.
2. The method of measurement.

M. le Président. — It would appear that we are in complete agreement as to involved in the first part of the second proposition. It was in

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(¹) Cette activité pourrait être définie comme il suit : Le courant produit par les atmosphériques dans l'appareil récepteur serait rectifié et chargerait un condensateur shunté par une résistance (méthode de Curtiss). On évaluerait le courant traversant cette résistance. On réaliserait ensuite le même courant en faisant agir sur le dispositif récepteur un émetteur auxiliaire. Le champ produit par l'émetteur à l'endroit où se trouve le récepteur (évalué en microvolts par mètre) serait considéré comme égal au champ moyen produit par les atmosphériques.

order to facilitate discussion on the point raised by Dr. Dye that I sub-divided this proposition.

The Chairman describes the Curtiss method mentionned in the proposal, stating that it had been used also in Great Britain and that the French Committee now suggests its general adoption.

M. le Président. — Are there any remarks to the practicability of this method.

Dr. Austin observes that he has not himself used the method and could offer no opinion.

M. Mesny. — Il y a-t-il d'autres définitions de l'intensité des atmosphériques?

Prof. Appleton. — The definition proposed seems to me quite satisfactory if the method contemplated by the Chairman is used.

What is measured in such a method is the rate of change of intensity with the time. It is this quantity which is of importance in loop reception.

M. le Président. — There appears then to be no objection to parts one and two of the second proposition. As for the third part, dealing with the width of the frequency band, it seems to me that the width of 500 cycles per second is impracticable. In Great Britain we are much troubled by signals interfering with the reception of atmospherics, and we have been compelled to use a band width of 25 cycles per second. It may be that in France Captain Bureau is more fortunate in respect of interference by signals.

Capitaine Bureau. — On ne peut vaincre le brouillage par les signaux qu'en restreignant l'étendue de la bande, mais cela nécessite l'emploi d'appareils très coûteux. Telle est la raison pour laquelle la proposition française parle d'une bande unique pour tous les pays.

M. le Président. — As Captain Bureau has pointed out, this question is mainly an economic one. While unwilling to increase the demands on the time of members by the multiplication of Sub-Committees I propose that a small Sub-Committee might be appointed to draft a definition of the quantity to be measured and to prepare a general specification for the apparatus to be used.

General Ferrié. — Il faudrait en même temps envisager l'aide éventuelle de l'Union ou des Comités Nationaux aux laboratoires qui ne possèdent pas les fonds nécessaires à l'achat des appareils. M. Robert Goldschmidt pourrait utilement faire partie du Sous-Comité.

M. Appleton propose de nommer : M. le Président, MM. Bureau, R. Goldschmidt, Kennelly, van der Pol, comme membres de ce sous-comité, ce qui est approuvé par la Commission.

La séance est levée et la prochaine réunion est fixée au vendredi 14 septembre à 11 heures.

Séance du Vendredi 14 Septembre 1928

Meeting of Friday, September 14, 1928

La séance est ouverte à 11 h. 45.

The Chairman reads the report of the Sub-Committee (¹).

L'assemblée applaudit l'offre généreuse de la General Electric Company of America, présentée par M. Snyder, et mettant gracieusement à la disposition de l'U. R. S. I. les appareils de mesure.

The Chairman remarks that no general comment on the report having been made, he proposes to vote on the resolutions of the Sub-Committee.

Ces résolutions sont admises à l'unanimité.

He then proposes to examine how many sets

(¹) Annexe 3, p. 41.

of apparatus should be alloted to each of the National Committees.

Après un échange de vues, la Commission propose de doter :

Pays représentés à l'Assemblée Générale.

La Belgique et le Congo : de 3 appareils.
Les Etats-Unis : de 6 appareils.
La France (et Colonies) : de 6 à 7 appareils.
La Grande-Bretagne : de 2 appareils.
L'Italie : de 3 appareils (sous réserve de ratification).
Le Japon : de 3 à 4 appareils.
Les Pays-Bas : de 2 appareils.

ce qui représente un total de 30 appareils environ.

M. Parkinson wants to know how much attentions the apparatus requires from laboratory personnel.

M. le Président. — That of course, depends of the quality of the particular apparatus and we may be assured of the very high excellence of that to be provided. The experimental apparatus used in Great-Britain is very easily handled and requires no more than 20 minutes work per day from a scientific assistant and not more than one to one and a half hour per day from the technical assistant entrusted with the maintenance of batterie... What does M. Snyder think about it?

M. Snyder. — I agree with you.

M. Parkinson suggests that the Bureau of Standards should make use of apparatus for measuring on each of the six proposed frequencies.

M. van der Bilt. — Pour le travail à effectuer, devons-nous faire des observations de jour et de nuit; les vingt minutes dont parlait M. le Président s'appliquent-elles au jour et à la nuit?

M. le Président. — The proposed apparatus would be a continuously recording one and the twenty minutes mentioned represents the time necessary for verifying the calibration and constancy of the apparatus. This operation would normally be carried out at a convenient hour in the morning, probably between 9 a. m. and noon. No night work would therefore be involver in connection with the recording scheme.

I propose to the Commission that we should nominate a sub-commission to discuss with the Company the detailed design and production of the apparatus and to supervise its distribution.

Dr. Austin supports this proposal.

Prof Appleton suggests that this Sub-Commission should be very small and should in fact be composed of the Chairman and M. Snyder.

Cette proposition est adoptée.

M. le Président. — We may now examine the third proposal.

Capitaine Bureau en donne lecture :

» Troisième proposition. — Il serait désirable que chaque pays, outre la station spécialement équipée pour la mesure absolue de l'activité des atmosphériques, assure un enregistrement continu qualitatif de l'activité des atmosphériques dans un certain nombre de stations (1 par 100,000 km²). Cet enregistrement pourrait encore se faire en utilisant la méthode Curtiss. Mais il nécessiterait des installations moins dispendieuses que la mesure en valeur absolue de l'activité.

» Pour compléter ces enregistrements, on pourrait utiliser dans chaque pays un certain nombre de postes récepteurs assurant un trafic régulier en leur demandant de noter heure par heure l'intensité et la fréquence des atmosphériques. On pourrait ainsi tracer pour chacun d'eux et pour tous les jours de l'année des courbes qui permettraient de déterminer approximativement la variation diurne. Ces courbes pourraient être complétées par des indications relatives aux gênes causées au trafic par les atmosphériques. »

M. Snyder. — This proposal may be accepted in view of the fact that the commercial stations normally take hourly records of the atmospheric disturbances and enter them in registers.

M. le Président. — Consequently, the National Committees ought to ask commercial firms and

administrations to communicate to them the logs of atmospherics disturbance which form part of their normal traffic records.

On the proposal for supplementary aural observations I would say that in Great Britain scientific investigation of atmospherics is almost entirely dependent on the Radio Research Board. Mr. O. F. Brown who is the secretary of that board may care to indicate the policy of the Board in this connection.

M. Brown. — The policy of the Radio Research Board is to give financial support only to researches of hight quantitative precision. This policy was adopted partly as a result of the inconclusive results of prewar investigations by aural method.

The Chairman proposes to divide the third proposal into two parts and to consider first the part dealing with the continuous recording relative measurement by the Curtiss method.

M. Snyder. — I do not think it is desirable to collect these relative observations. The work of reduction would be enormous and the results of little value considering the doubtful scale value of the individual measurements.

We must remember the very heavy work that will be involved in the great volume of data provided by 30 or 40 stations carrying out absolute measurements.

Capitaine Bureau. — L'objet de la proposition est l'étude dans un pays déterminé des corrélations entre les phénomènes de propagation et les conditions météorologiques. Mais l'intention n'est pas du tout de confronter ces résultats qualitatifs avec ceux des mesures absolues envisagées plus haut.

M. Snyder. — I agree with this conception.

M. le Président. — It would therefore appear that although there may be in some countries economical difficulties there is no objection in principle. As Captain Bureau has made it clear that this question is essentially a national one for each country, each National Committee should be asked to examine the question from their own point of view.

As for the second part of the third proposal (utilization of results from stations handling regular traffic, we shall ask each National Committee to approach into contact with the commercial firme organisations and public administrations within their range.

We have now to examine the fourth French proposal dealing with the distribution of the frequency bands within which the absolute measurements are to be made.

The list of frequencies put forward as the middle points of the bands of 25 cycles per second are as follows :

12 000 Kc/sec.;
4 000 » ;
1 500 » ;
130 » ;
65 » ;
20 » .

Prof. Kennelly. — The frequencies seem somewhat irregularly distributed. The scale of selected frenquencies might the perhaps adopt a more regular progression.

Capitaine Bureau. — Il n'y a pas d'inconvénient à la modifier. Ces bandes ont été choisies parce que des observations y avaient déjà été faites.

M. le Président. — It is then the desire of the Commission that the sub-commission should use these suggested bands as a general guide in the final design of the installations, but that they are authorised to re-distribute the bands in any way that appears desirable.

La séance est levée à 12 h. 30 et réouverte à 15 heures.

* * *

The Chairman reads the fifth French proposal :

« Le Comité Français propose qu'en vue d'apporter des documents nouveaux sur la portée des atmosphériques, il soit recommandé de diriger d'une façon générale les observations de telle manière qu'elles aboutissent à des tracés sur cartes, mêmes rudimentaires, de courbes d'égale intensité des atmosphériques et au tracé de cartes d'isochrones des variations rapides et importantes de l'activité des atmosphériques. »

Aucune objection n'étant présentée, cette proposition est adoptée.

The Chairman remarks that the proposals of the British National Committee (¹) were drafted after informal discussions between Captain Bureau and himself with a view to the embodiment of a common policy.

« For this reason the essence of a considerable portion of them have already been dealt with in the discussions of the French proposals, and it is therefore unnecessary the review them in full detail.

» The first proposal (Meteorological relations) is already included in the French proposals.

» The second (Range of Atmospherics) and the third (Sources of Atmospherics) deal with radiogoniometric methods. Time does not permit of their discussion at this stage. Further discussion of the radiogoniometry of atmospherics must be left over to another occasion. Meanwhile, I may say that I have recently supervised the manufacture of two Cathode Ray Direction Finders for the American Navy Department. It is to be hoped that the use for these instruments, in addition to those already in operation in Gret Britain, may constitute a further important step in international observations on atmospherics.

» The fourth proposal deals with the use as time marks of the syllables of a broadcast talk, the syllables interfered with by atmospherics being marked on a typescript copy circulated in advance. This method involves the collaboration of amateurs and may therefore appropriately be left for consideration by Commission IV. »

The Chairman thanks the Members of the Commission for their collaboration.

La séance est levée à 15 h. 30.

(¹) Fascicule 2, annexe 3

Travaux de la Commission de liaison avec les Opérateurs, Praticiens et Amateurs

Papers of the Commission of Cooperation with the Operators, Practisers and Amateurs

La Commission de Liaison qui a siégé à Bruxelles, en 1928, était composée des savants suivants :

The Commission of Cooperation which was held in Brussels, in 1928, was composed of the following savants :

Angleterre :	Dr. E. H. RAYNER, D. Sc. National Physical Laboratory.
Belgique :	Colonel B. E. M. WIBIER.
États-Unis :	Prof. A. E. KENNELLY, of the Harvard University.
France :	Ing. P. BRENOT, Administrateur-Directeur de la Société Française Radio-Électrique.
Italie :	Prof. G. VANNI, Directeur de l'Institut Central Militaire de Radiotélégraphie.
Japon :	Prof. H. NAGAOKA, Professeur à l'Université de Tokyo.
Pays-Bas :	Prof. C. L. VAN DER BILT, Professeur au Laboratorium voor Natuurkunde en Electrotechniek. Delft.

Les séances de la Commission étaient présidées par M. le Profʳ Vanni.

The meetings of the Commission were presided at by Profʳ Vanni.

Séance du Mercredi 12 Septembre 1928

Meeting of Wednesday, September 12, 1928

La séance est ouverte à 15 h. 45.

M. le Président. — Je remercie mes collègues de l'honneur qu'ils m'ont fait en me confiant la présidence de cette importante Commission. La sphère de la Commission, déjà vaste auparavant, a encore été augmentée par l'Assemblée Générale de Washington qui lui a confié la liaison avec les sciences connexes de la radio, et j'estime que, étant donnée l'importance des questions à étudier, il eut mieux valu confier la présidence à quelqu'un de plus capable que moi; quoi qu'il en soit, j'en accepte l'honneur et vous en remercie.

Notre travail ne sera profitable que s'il est bien coordonné, il consiste à coordonner les travaux des radio-amateurs, et, chose plus difficile, à coordonner avec la radio, les travaux des sciences se rapportant aux phénomènes solaires. Quoique ces sciences soient, elles aussi, à leurs origines, il importe de remarquer qu'il y a 60 ans déjà le Père Secchi avait entrevu la corrélation entre l'activité solaire et les phénomènes magnétiques.

Comme le temps dont nous disposons est limité, il convient d'entamer notre travail en établissant un programme que je propose de subdiviser comme suit :

1° Liaison avec les amateurs, ce qui constitue l'ancien programme;

2° Liaison avec les sciences connexes, ce qui constitue la partie nouvelle de notre programme.

Comme cela a été fait en 1927, il y aurait lieu d'établir un rapport sur l'activité des amateurs depuis 1927, mais malheureusement, les renseignements nous font défaut, aussi, je crois qu'il serait plus utile et urgent d'étudier la deuxième partie de notre programme.

Si vous acceptez ma manière de voir, on pourrait subdiviser cette partie elle-même en trois chapitres :

1. Corrélation entre la radio et l'activité solaire;
2. Corrélation entre la radio et la météorologie;
3. Corrélation entre la radio et la géophysique.

D'autre part, dans le courant du mois de juillet, il s'est tenu à Leyde un Congrès d'Astronomie chargé d'étudier la relation entre l'activité solaire et la radio. Je crois que le Général Ferrié a participé aux travaux de ce Congrès et je serais heureux de le voir nous renseigner au sujet de ce qui a été fait à ce Congrès.

Général Ferrié. — C'est avec plaisir que je donnerai satisfaction au Professeur Vanni, mais je dois d'abord faire remarquer que la division proposée par M. Vanni n'est peut-être pas très sûre. En effet, certains phénomènes de la météorologie et de la géophysique sont dus à des actions secondaires de l'activité solaire.

Le Conseil International de Recherches a créé un certain nombre de Commissions mixtes comprenant différentes sous-Commissions; en particulier il créa la Commission des Relations entre les phénomènes solaires et terrestres sous la Présidence de M. Chapman. Cette Commission fonctionne depuis trois ou quatre ans. A la suite de sa première réunion qui eut lieu à Bruxelles, il y a deux ans, elle publia le compte rendu de ses travaux qui fut distribué aux Comités Nationaux de l'U. R. S. I.

Cette année, les travaux furent continués à Leyde et on est arrivé à la conception suivante : il ne faut pas espérer une solution rapide des problèmes posés. En outre, on a admis qu'il ne suffisait pas que les divers spécialistes travaillassent chacun de son côté, il faudrait des observations simultanées, les phénomènes solaires étant extrêmement rapides. Il faudrait créer des observations organisées de façon à observer simultanément la constance solaire, l'action des taches, la position des taches, l'ionisation de l'air et la propagation des ondes. C'est la partie difficile du problème qui, étant donné la question financière, ne peut pas être résolue par nous, mais chacun dans notre pays nous pouvons agir pour que la question financière soit aplanie. En attendant les observatoires pourraient s'adjoindre des spécialistes radio ou acquérir des appareils.

Tout le travail fait à Leyde sera publié et distribué incessamnent.

En même temps, ont été émises certaines suggestions intéressantes pour nous, telle celle de M. Stormer, auteur de théories sur les aurores boréales : certains phénomènes d'écho semblent montrer qu'il y a des échos qui arriveraient après une durée de l'ordre de quelques dixièmes ou même de 1 ou 2 secondes, ces échos seraient produits par des nuages d'électrons dans l'espace interstellaire.

Si vous désirez plus de détails à ce sujet, je me tiens à votre disposition.

Je tiens à ajouter encore quelques mots au sujet du Congrès de Leyde.

On s'est occupé de la couche d'ozone qui existe dans l'atmosphère à une hauteur de 50 km. On a rappelé qu'il existe également une couche où la température s'élève et redevient celle de la terre, c'est la couche d'inversion de la température; enfin, certains astronomes ont également trouvé une couche d'absorption. Il existe peut-être des relations entre ces couches et celle de Kennelly-Heaviside-Nagaoka... Il importe d'étudier la corrélation entre l'existence de ces couches et l'activité solaire.

La conclusion de cet exposé est qu'il serait utile que notre Commission prenne contact avec la Commission mixte pour savoir comment nous pourrions lui prêter notre concours.

M. le Président. — Au sujet de la remarque faite par le Général Ferrié, j'ai uniquement proposé la subdivision en trois points pour faciliter notre travail d'aujourd'hui.

Je me permets de demander au Général Ferrié si Stormer a eu des vérifications expérimentales de la suggestion émise.

Général Ferrié. — Non, Stormer a seulement entendu dire que certains observateurs avaient remarqué ces phénomènes.

M. le Président. — Il serait utile de se mettre en rapport avec Chapman pour l'étude des échos.

Général Ferrié. — Il existe toute une categorie d'échos qui ne correspondent pas aux échos décalés du laps de temps nécessaire pour effectuer le tour de la terre. Si mes souvenirs sont bons, je crois qu'un expérimentateur a obtenu jusqu'à cinq échos ne correspondant pas au tour de la terre. Il semble donc qu'il existe deux catégories d'échos bien différentes.

M. le Président. — La proposition du Général Ferrié que notre Commission se mette en rapport avec la Commission mixte me semble devoir être prise en considération.

Dr. Rayner. — A few years ago a serious attempt was made through the Radio Research Board to obtain from amateurs assistance and information of value on various aspects of radio transmission, long distance reception, fading, etc. Very few results of any value were obtained; in these days results without a measurement of some kind can generally have but little value.

It has been found, however, that if amateurs are provided with simple apparatus, good results may follow. For instance, during the eclipse of the sun last year, some amateurs gave valuable assistance in carrying out measurements of intensity of the reception of special transmissions organised by Professor Appleton and the British Broadcasting Corporation, on behalf of the Radio Research Board.

In England discussions have been held between workers on radio transmission with such people as Sir Frank Dyson, the Astronomer Royal, Sir Arthur Schuster, Dr. Simpson of the Meteorological Office, Professor Chapman and Dr. Chree, and we have started with the study of correlation between magnetic phenomena and radio transmission. When an unusual magnetic disturbance is recorded at the Magnetic Laboratory at Eskdalemuir in Scotland, information is sent to Teddington, and it is distributed to a number of workers and organisations. One result of this has been that it appears that certain characteristics of long wave transmission are influenced for a considerable number of hours after the occurrence of a magnetic disturbance; and absence of correlation as regards change of radio reception may be due to the fact that the transmitting medium is already in its changed condition by reason of the effect associated with one or more magnetic disturbances which have occurred some time previously.

Général Ferrié. — On admet que le phénomène signalé par le Dr. Rayner est dû aux électrons émis par le soleil : le temps mis par les électrons du soleil à la terre étant environ de deux jours, plus exactement 45 heures.

L'organisation signalée par le Dr. Rayner est très intéressante. En France, nous avons une organisation semblable pour l'étude des phénomènes sismiques. Les postes de Bordeaux et F. L. émettent des bulletins météorologiques.

Déjà en France, à Meudon, Deslandre a outillé son laboratoire d'astro-physique à l'aide de sonneries prévenant les observateurs des perturbations magnétiques. Mesny a installé, également à Meudon, une série d'appareils pour effectuer des mesures radio. Nous avons donc là un exemple d'observatoire mixte; on devrait en organiser plusieurs, mais, en attendant, l'idée du Dr. Rayner est excellente et je l'appuie.

Prof Nagaoka. — We possess a magnetographic station in Kakioka not far from Tokyo. It was proposed to telegraph the coming of magnetic storms to the Ministry of Communications; this one sends radiograms in Japan and in Corea. This service operated during two years, but it does not seems to give accurate informations.

Dr. Rayner. — I should like to add a few words to what I have said. In England there is an organisation for the study of the position of sources of atmospherics.

The direction of the source of an atmospheric is indicated on a Kathode ray oscillograph, using a receiving circuit of two coils at right angles connected to the two pairs of plates of the oscillograph. With two such equipments, connected by telephone, one at Slough near Windsor, and the other at Cupar in Scotland, about 800 kilometres apart, the source of atmospherics can be determined; and arrangements are being made to inform the Meteorological Office daily of the results of the observations.

Général Ferrié. — Je propose que la Commission émette un vœu à transmettre à l'Assemblée Générale, pour que des bulletins soient émis par radio dans différents pays sur l'activité solaire et les phénomènes radio-physiques, afin de nous permettre de réunir des observations sur la nature des orages magnétiques et sur les phénomènes qui les accompagnent. Ces bulletins seraient donnés, par exemple, en même temps que les bulletins sismologiques et autres qui suivent les signaux horaires.

Je demande au Président de nous soumettre le texte d'un vœu et je propose que quelqu'un soit chargé d'établir un code pour la transmission des bulletins.

M. le Président. — Je crois que la proposition du Général Ferrié ne rencontrera aucune objection. Il conviendrait de déterminer quelle est la collaboration que nous pouvons attendre des amateurs. Il y a aussi la question financière à envisager. Notre Union devrait étudier les moyens simples, ne nécessitant pas de grandes dépenses et permettant de mettre des appareils entre les mains des amateurs. On pourrait peut-être envisager de donner des appareils simples comme récompense aux amateurs les mieux qualifiés, qui nous communiqueraient des renseignements intéressants.

Général Ferrié. — Je crois qu'au début on pourrait se contenter de demander aux amateurs de suivre les bulletins transmis par les grandes stations, ils pourraient ainsi nous envoyer les résultats de leurs observations sur l'intensité des signaux reçus, le fading, etc. La question des appareils, me semble-t-il, devrait être remise à plus tard.

Dr. Austin. — In America, the collaborated work with the astronomers is very close; the fading's measurements made previously were begun again at the Harvard Observatory. Actually the numerical results obtained during several years in my laboratory have been examined and they are of the same nature as those of Dr. Rayner.

I think it is very desirable to get the collaboration of amateurs, but disappointments are to be feared if some precautions are not taken. I would perhaps be good to form young amateurs by the help of persons skilled in the matter.

Capitaine Bureau donne quelques précisions sur la réception du bulletin météorologique émis chaque jour sur 75 m. par l'Amérique.

« Ce bulletin a été reçu régulièrement pendant toute l'année, dit-il, sauf un jour du mois de juillet dernier, où un orage magnétique assez violent avait éclaté et où il n'a été reçu ni à Paris, ni à Brest, ni à Hambourg.

» Depuis novembre 1927, aucune autre interruption ne fut constatée.

» Nous avons, de plus, en France, une dizaine d'amateurs faisant des observations assez sérieuses. S'ils avaient été prévenus par radio ils eussent fait des observations du phénomène. »

M. le Président. — A ce propos nous avons observé quelque chose d'analogue en Italie, où les communications entre le Citta di Milano et San Paolo ont fait défaut du 7 juillet à 22 heures au 9 juillet à 4 heures (Temps de Greenwich).

Profr Kennelly. — Considering the importance of the communications done on cooperation that have been reported, it would perhaps be useful if the Commission to formulated a recommendation for the cooperation of the U. R. S. I. with astronomers, meteorologists and geophysicists.

M. le Président. — Comme l'heure est avancée, je propose de lever la séance. La prochaine réunion aura lieu vendredi 14, à 15 h. 30.

La séance est levée à 17 h. 5.

Séance du Vendredi 14 Septembre 1928

Meeting of Friday, September 14, 1928

La séance est ouverte à 16 h. 40.

M. le Président. — Notre temps étant très limité, nous devrons nous borner à ne traiter que les questions les plus importantes.

Je vais tout d'abord vous donner lecture de la traduction du vœu rédigé par le Dr Rayner et relatif à la liaison avec les diverses sciences.

« En considération de la complexité et de la dépendance mutuelle des phénomènes de radio transmission à ceux de la géophysique, de la physique solaire et de la météorologie, il a semblé que la collaboration des personnes qui cultivent ces sciences était nécessaire pour obtenir un progrès satisfaisant.

» Dans ce but, on est d'avis que des observations simultanées des phénomènes se rapportant à ces sciences, seront de grande efficacité pour la solution de beaucoup de problèmes importants, ayant à la fois caractère théorique et pratique.

» La Commission exprime le vœu que le Bureau du Secrétariat Général de notre Union puisse étudier les moyens d'action appropriés pour réaliser ce programme et obtenir la coopération des différentes organisations scientifiques internationales de l'Union. »

Je prie M. Le Corbeiller de donner lecture du texte original.

Ingr Le Corbeiller donne lecture du texte original rédigé comme suit :

« It is resolved that, in view of the complexity and interdependence of the phenomena of radio transmission and those of geophysics, solar physics and meteorology, the mutual collaboration between the workers in these sciences is necessary for their satisfactory development.

» It is considered that simultaneous observations of phenomena in these fields will be of great mutual assistance in solving many important theoretical and practical problems.

» The Commission desires therefore to instruct the Secretariat to take such action as may be suitable to bring about cooperation with the corresponding international organisations. »

M. le Président. — Quelqu'un a-t-il une observation à faire au sujet de ce texte?

Dr. Rayner. — The translation of Profr Vanni is better than my text, I propose to adopt the translation.

M. le Président. — Nous adopterons donc ma traduction comme texte à présenter à l'Assemblée Générale.

Nous allons passer maintenant à une autre question : c'est l'étude des relations existant entre les phénomènes solaires et magnétiques.

Le Général Ferrié a émis le vœu que l'on publie à l'avance des bulletins d'informations géophysiques à transmettre aux amateurs; ces bulletins annonceraient le début des orages magnétiques, les phénomènes météorologiques en général, les éclipses et autres phénomènes de ce genre.

Quelqu'un a-t-il une observation à formuler à ce sujet?

Comme il n'y a pas d'observations, nous formulons le vœu que ces bulletins soient préparés et publiés.

Général Ferrié. — Il faudrait que dans chaque pays les Comités Nationaux se mettent en relation avec les observatoires d'astrophysique et de géophysique pour recevoir l'annonce des orages, et s'entendent avec les stations d'émission pour la radio-diffusion des renseignements reçus; quelques stations suffiraient.

Il faudrait également établir un code pour la radio-diffusion des bulletins.

Peut-être le Secrétariat Général pourrait-il préparer le travail et le communiquer aux Comités Nationaux.

En France, la station de Bordeaux pourrait bientôt commencer des émissions de ce genre.

Dr. Austin. — Could those formularies be sent at the same time as the meteorological formularies?

Capitaine Bureau. — Il n'y a rien d'impossible à cela, c'est une entente à réaliser.

Parmi les bulletins météorologiques d'Amérique, deux sont spécialement destinés à l'Europe, ils seraient tout désignés. Il y a également les bulletins météorologiques d'Europe destinés à l'Europe.

M. le Président. — Le deuxième point à examiner est l'étude des phénomènes météorologiques en général. M. le Capitaine Bureau a fait l'an dernier un très remarquable rapport à Washington sur cette question; a-t-il eu des résultats du programme qu'il nous avait exposé?

Capitaine Bureau. — J'ai étudié dans quelles conditions le programme établi à Washington pourrait être réalisé, j'ai rencontré de grandes difficultés pour trouver des émetteurs convenables au point de vue de la stabilité, de la puissance, du prix, et pour lesquels on puisse avoir la certitude qu'ils restent semblables à eux-mêmes pendant plusieurs années. Ces dernières conditions ne sont pas remplies par les stations commerciales, il faut donc s'adresser aux laboratoires ou aux stations publiques. Une seule semble convenir actuellement, c'est celle de la Marine Américaine à Arlington. Cette station comprend quatre postes stabilisés au quartz et travaillant sur trois harmoniques (4 015 kc/s). La station d'Arlington transmet des bulletins météorologiques journellement pendant un total de 4 à 5 heures. Depuis quelque temps le poste de Bellevue fait de plus des émissions sur 15 mètres.

Je proposerais donc que le Secrétariat Général s'entende avec le Service des Communications de la Marine à Washington pour établir un programme d'émissions à transmettre aux amateurs du monde entier, c'est un programme plus restreint que celui présenté l'an dernier, mais beaucoup plus réalisable.

M. le Président. — Je suis d'avis de transmettre la proposition de M. le Capitaine Bureau au Secrétariat Général.

Un des membres ici présent connait-il d'autres stations pouvant faire des émissions de ce genre? En formulant cette demande, je songe aux amateurs ne possédant pas d'appareils capables de recevoir la station d'Arlington.

Général Ferrié. — La création d'une station ayant une émission d'une grande constance est une œuvre bien difficile, fort coûteuse et demandant beaucoup de temps. Nous espérons que la formation du Centre Scientifique dont on nous a parlé ce midi, pourrait nous permettre d'espérer la création d'une station semblable permettant de s'occuper de toutes les mesures intéressant nos travaux.

M. le Président. — L'an dernier à Washington nous avons reçu une proposition du Comité Anglais au sujet des relations avec la météorologie, on avait suggéré de fixer internationalement un jour par mois pour ces expériences; je demande ce qui a été fait à ce sujet.

M. Watson Watt. — It was not found possible to adhere accurately to the programme of one observation per month, and a alternative programme was adopted in accordance with which we had the collaboration of amateurs in various countries who had the double qualifications of skill in meteorology and in radio reception.

The object of the observations carried out under the auspices of the Royal Meteorological Society was to note on a typescript circulated in advance, the syllables of broadcast talk on which were heard superposed atmospherics. This particular type of observation, involving the coincidence in time of two phenomena reaching the observer's ear, is peculiarly suited for making effective use of amateur collaboration. We had observers in Norway, Germany, France, Spain, North Africa and Madeira in addition to the observers in Great Britain. The quantitative accuracy of the results obtained was far in excess of the Committee's expectations, and the combination with these observations of directional observations on the same atmospherics provided us with conclusive evidence as to the reception of atmospherics at great distances from their sources. The results of the radiotelegraphic observations have been collected and published in a preliminary report, but the Committee's still engaged on an examination of meteorological conditions at the times of observation, and it is hoped that a full report may be published in time for the next Assembly.

M. le Président. — Nous arrivons au troisième point de notre programme, c'est-à-dire aux parasites.

Je me permets de demander les moyens les plus simples à mettre en œuvre pour permettre aux observateurs de résoudre le problème de la détermination de la fréquence et de l'intensité des parasites et de la radiogoniométrie de ces parasites. Je demande l'avis de M. Watson Watt.

Général Ferrié. — Cette question fait partie du domaine de la troisième Commission.

M. le Président. — Je voudrais savoir parmi les méthodes employées quelle est la meilleure à préconiser pour les amateurs. Il existe, par exemple, la méthode du signal interrompu, où les signaux sont envoyés toutes les 20 ou 30 secondes; on pourrait rapprocher les intervalles de temps.

Dr. Austin. — Is this method better than the one of the dictated text put forward by M. Watson Watt?

M. le Président. — Je n'ai pas comparé les deux méthodes.

Général Ferrié. — L'avantage de la méthode préconisée par M. Watson Watt est de ne pas nécessiter d'émissions spéciales.

Dr. Austin. — I think that method would permit to the amateurs to note the interruptions more correctly.

M. le Président regrette de devoir terminer la séance, le temps dont la Commission disposait étant épuisé, et remercie de leurs concours les membres de la Commission.

La séance est levée à 17 heures.

Travaux de la Commission de Radiophysique

Papers of the Commission of Radiophysics.

La Commission de Radiophysique qui a siégé à Bruxelles en 1928 était composée des savants suivants :

The Commission of Radiophysics held in Brussels in 1928 was composed of the following savants :

Belgique :	Prof^r DACOS, de l'Institut Électrotechnique Montefiore.
États-Unis :	Prof. A. E. KENNELLY, of the Harvard University.
France :	Ing. Ph. LE CORBEILLIER, D. Sc. Service d'Études et de Recherches Techniques de l'Administration des P. T. T.
	Ing. SALOMON de l'Administration des P. T. T.
Italie :	Prof. G. VANNI, Directeur de l'Institut Central Militaire de Radiotélégraphie.
Japon :	Prof. H. NAGAOKA, Professeur à l'Université de Tokyo.
Pays-Bas :	D^r BALTH. VAN DER POL, du Natuurkundig Laboratorium der N. V. Philip's Gloeilampenfabrieken.

Les séances de la Commission étaient présidées par M. le D^r van der Pol.

The meetings of the Commission were presided at by Dr. Balth van der Pol.

Séance du Mercredi 12 Septembre 1928

Meeting of Wednesday September 12, 1928

La séance est ouverte à 14 h. 45.

M. le Président. — La fondation de cette Commission fut décidée, il y a un an, à Washington, et des comptes rendus des séances il appert que tous les membres présents étaient d'accord pour constituer cette Commission qui devait étudier divers sujets ne rentrant pas dans le cadre d'étude des autres Commissions.

Jusqu'à présent, le travail de cette Commission n'a pas été tout à fait défini, et peut-être pourrais-je citer quelques sujets ou plutôt définir notre travail d'une façon plus précise, si cela vous agrée. Mais tout d'abord je crois qu'il faudrait discuter l'appellation à donner à cette Commission.

Vous connaissez tous les raisons pour lesquelles la création de cette Commission fut décidée; de nombreuses questions à étudier n'entraient dans le domaine d'aucune des quatre Commissions, par exemple, des sujets relatifs à la théorie des oscillations linéaires, des oscillations non linéaires; des questions relatives à la détection, à la modulation, les cellules photoélectriques, etc.

Quelqu'un a-t-il une objection au nom donné à la *Commission des Oscillations*?

J'ai entendu dire que certains délégués de l'Amérique lui avaient opposé quelques critiques, le D^r Kennelly pourrait peut-être nous les exposer?

Prof. Kennelly. — I have not heard any official statement of objection against this name.

I have only heard the idea expressed in a general way that the name is not very distinctive and that since electrical oscillations entered into radio communications in a great variety of ways, that some more distinct name might be selected with advantage.

Ing. Le Corbellier. — Nous avons cherché mieux sans succès et nous avons pensé que personne n'était plus qualifié que le Profr Kennelly pour trouver un nom convenable.

Prof. Kennelly. — I do not like to make any suggestion at this moment, but if you will permit me to confer with some of the members, I shall be glad to take a decision at a later period.

M. le Président. — Je crois que le mieux serait de récapituler les points que certains d'entre nous estiment devoir faire partie du domaine de la Commission V. Si nous partons de l'idée d'oscillation, nous pouvons diviser le sujet de la façon suivante : systèmes oscillants linéaires et systèmes oscillants non linéaires. Le premier groupe comprendrait l'étude des oscillations linéaires électriques, mécaniques, élastiques, acoustiques, ultra-sonores, les générateurs et transformateurs linéaires et les transformateurs d'oscillations d'une espèce en oscillations d'une autre espèce : hauts-parleurs, condensateurs parlants, quartz, appareils à magnétostriction, etc. Comme systèmes du second groupe, nous pouvons citer : les générateurs d'oscillations à source d'énergie continue, les appareils contenant du fer, les changeurs de fréquence, la détection, la modulation, etc.

Ceci ne constitue qu'un schéma général et je demande aux membres présents de me donner leur avis sur le travail à effectuer par la Commission V.

Il est évident qu'une partie du travail confié à la Commission pourra empiéter sur le domaine de quelqu'autre Commission, je proposerai donc que des réunions avec d'autres Commissions soient envisagées.

Profr De Donder. — Si j'ai bien compris, cette Commission aurait un caractère plutôt théorique, j'estime qu'il doit en être ainsi et que l'on peut espérer avoir de la sorte des vues plus hautes; je vois un intérêt profond à cette Commission, elle aura un but plus synthétique que les autres.

La science que nous étudions est en formation et fait de rapides progrès. Il y a pour nous un intérêt majeur à ne pas perdre contact avec une branche de la science qui se rattache très fort aux problèmes qui nous occupent et qui fait actuellement des progrès rapides; j'ai cité les théories des Sommerfeld, de Broglie, Schrodinger... qui étudient les radiations sous un point de vue nouveau.

Je suis très enthousiaste du but proposé à la Commission des Oscillations, c'est une section indispensable, garante des multiples progrès qui se feront en radiotélégraphie.

M. le Président. — Revenant sur le nom de la Commission, la revue « Experimental Wireless » comporte après diverses rubriques se rapportant aux différentes branches de la radiotélégraphie, une rubrique intitulée : « Non radio subjects ». Ce que vient de dire M. le Profr De Donder me porte à croire que notre Commission pourrait s'intituler elle « No yet Radio Subjects ».

Il n'y a pas de doute que l'on a tout intérêt à étudier des phénomènes plus généraux que ceux que l'on applique dans la pratique. Pour ma part, j'ai trouvé que je comprenais mieux les propriétés des triodes dans la région ordinaire après avoir porté, mettons, le potentiel de grille à + 100, celui de plaque à — 100 V.

Prof. Appleton. — Although I am not a member of this Commission, I should like to say a few words to state the reasons of the abstention of Great Britain. We do not find the need of this Commission on an international point of view; an international co-operation is not requisite to the improvement of the questions which have just been named. Thinking at the enumeration of subjects made by the Chairman, it seems that a better name that « oscillations » could be give to the Commission. Some of the quoted subjects, photo electrical cells for instance, do not belong to the oscillations; a more general name could be used. I should like to see this Commission as an auxilary of the others and particularly of Commission I.

M. le Président. — A la première objection du Profr Appleton, je répondrai en lui rappelant que nous sommes une émanation du Conseil

International de Recherches qui juge utile une coopération internationale pour l'avancement des questions d'ordre tout à fait théorique, ou bien qui pourraient à la rigueur être étudiées par des chercheurs isolés comme le prouve l'existence des Unions mathématique, physique, chimique, etc.

Général Ferrié. — J'appuie l'idée de M. van der Pol et j'ajoute que les réunions que nous avons, permettent de nous connaître les uns les autres, et d'échanger directement nos idées et nos vues sans aucun intermédiaire. Le Conseil International des Recherches l'a compris puisqu'il existe d'autres Unions Internationales s'occupant de sciences telles que la biologie, les mathématiques, ne nécessitant pas de collaboration internationale.

M. le Président. — J'ajoute que je suis tout à fait d'accord avec le Prof^r^ Appleton au sujet du deuxième point qu'il a soulevé et je ne doute pas que nous arrivions à trouver un nom convenable pour la Commission. Peu importe le nom, le travail seul importe.

Je n'ai pas entendu d'observations au sujet du plan que j'ai exposé il y quelques minutes; quelqu'un aurait-il des remarques à formuler?

Prof. Kennelly. — I have only to remark that the list is very broad and general at present, and so long as it leaves room for any other material which may be found desirable and of the order; I see no objections whatever.

M. le Président. — Le temps a passé et je me permettrai de faire encore une remarque : la V^e^ Commission est actuellement constituée et son travail est en cours, mais le Prof^r^ Kennelly n'était pas à Bruxelles quand la constitution des Commissions fut faite, j'estime que celui-ci remplirait mieux que moi les fonctions de président et je le prie de bien vouloir me remplacer au fauteuil.

Prof. Kennelly. — I appreciate very much this offer but I think that the important works of Dr. van der Pol name him particularly to fill the place of President.

M. le Président. — Je remercie vivement M. le Prof^r^ Kennelly de son précieux témoignage. Nous suivrons donc le programme général.

Je crois que vu l'heure avancée, la seule chose que nous puissions faire à présent, est de décider la date de la prochaine réunion.

Dr. Hull. — I which to state that some members of the American delegation who are now present, asked me to bring up the question of nomenclature of vacuum tube constance and circuits and to get to know if the Commission would desire to include that among the topics to be discussed.

M. le Président. — Je m'en rapporte à la longue expérience de M. Van Der Bilt.

M. Van Der Bilt. — Le Comité Électrotechnique International étudie cette question. Nous devons faire attention à ne pas empiéter sur le domaine d'autres Commissions scientifiques; cependant, lors de la prochaine réunion du Comité Électrotechnique, je pourrais proposer un travail en collaboration.

Général Ferrié. — La question de la nomenclature a été en effet étudiée au Comité Électrotechnique, mais certaines de ses définitions nous ont paru donner lieu à quelques objections. Nous avons écrit pour exposer nos desiderata. Le Comité a décidé de nous consulter dorénavant et de nous soumettre ses travaux en ce qui concerne la Radio-électricité. J'estime que la V^e^ Commission pourrait utilement s'occuper des questions qui nous seraient posées par le Comité Électrotechnique.

M. Van Der Bilt. — J'appuie la proposition du général Ferrié, j'ajoute que le Comité Électrotechnique s'occupera aussi des symboles.

Lors de la prochaine réunion du Comité qui aura lieu à Berne à la fin du mois, je proposerai au Comité de soumettre à l'U. R. S. I. les symboles radio proposés.

D'après moi, pour la détermination des symboles, il faut une collaboration étroite entre le C. E. I., le C. C. I. et l'U. R. S. I.

M. le Président. — Je voudrais avoir l'avis du D^r^ Dye à ce sujet.

Dr. Dye. — I think that subject belongs to Commission V.

M. le Président. — La Commission V accepte alors volontiers cette mission.

Je viens de recevoir une communication du

Prof^{r} Manneback qui propose comme nom de notre Commission « Commission de Radiophysique ». Nous pourrions y réfléchir et en reparler à la prochaine séance.

Je propose de lever la séance. La prochaine réunion aura lieu le vendredi 14, à 14 h. 30.

La séance est levée à 15 h. 30.

Séance du Vendredi 14 Septembre 1928

Meeting of Friday, September 14, 1928

La séance est ouverte à 15 h. 30.

M. le Président. — Nous allons reprendre la question du nom à donner à la Commission. A mon avis, de toutes les propositions, la meilleure me semble celle de M. le Prof^{r} Manneback qui proposait de donner à la V^{e} Commission le nom de « Radiophysique ». Qu'en pense M. le Prof^{r} Kennelly?

Prof. Kennelly. — In our sub-committee, we also thought the best name to give was « Radiophysics ».

Dr. Austin. — I agree all the more that I had already proposed this name in 1927.

Général Ferrié. — Je me rallie à la proposition bien que l'on pourrait y faire quelques objections : la radiophysique comprend aussi l'étude d'autres phénomènes tels que les rayonnements corpusculaires, les rayons X, les rayons pénétrants, etc., mais en fait ceux-ci intéressent également la radiotélégraphie.

M. le Président. — Nous prendrons donc comme nom celui de « Radiophysique ».

Nous avons conversé entre nous et pensé que deux ou trois sujets pourraient être mis en avant et discutés avec fruit à cette réunion. Un de ces problèmes fut soulevé à la Commission de Propagation des Ondes, et concerne la variation de la fréquence et de l'intensité d'un signal émis à fréquence et intensité constantes lorsque les propriétés locales du milieu transmissif ne sont pas constantes. On a fait observer à la Commission de Propagation que lorsqu'on a à mesurer la variation de la fréquence de réception, spécialement avec les ondes courtes, il est très important de s'assurer que la fréquence qui est réellement transmise par l'émetteur est absolument constante, tout au moins dans les limites des possibilités techniques. Mais même quand cette fréquence est constante, une variation des propriétés du milieu transmetteur en fonction du temps, peut occasionner des variations au poste récepteur. Nous pouvons limiter notre étude à des approximations ayant un sens physique. Je pense que nous sommes tous d'accord pour admettre que ces variations des propriétés du milieu, particulièrement de μ, ε et σ sont des fonctions du temps ayant des variations autour de valeurs données.

J'aimerais que quiconque s'intéressant à la question donnât son avis sur ce problème.

Prof. Appleton. — The very interesting problem just mentioned, is similar to the one Fizeau studied a long time ago, problem in which he studied the interferences caused by the differences of phases of luminous rays emanated from the same luminous source and crossing dissimilar fluids such as air and water, in this case the quantity $\frac{1}{\sqrt{1-\mu^2}}$ interferes.

Dr. van der Pol thinks perhaps to the permanent phenomenon and not to the transitory phenomenon.

M. le Président. — Ce que j'ai en vue est plutôt le cas où le milieu a un ε à peu près constant, et où $\frac{1}{\sqrt{1-\mu^2}}$ à cause de la présence de nuages d'électrons dans l'atmosphère, a une valeur variable entre certaines limites constantes; cette valeur étant une fonction du temps.

Ing. Le Corbeillier. — Je comprends que les variations que vous envisagez pourraient être considérées comme dues au hasard et la répartition des amplitudes suivant la loi de Gauss.

Prof. Appleton. — I see the problem and I think that if we come back to the problem of Fizeau, we may look two cases over : in the first, the vibrations are longitudinal, the variations are due to the hazard, they do not alter the frequency but only the phase; in the second case, the vibrations are transversal and the waves are propagated perpendicularly with the speed of the medium, the frequence follows limited variations.

Prof^r Manneback. — Je suis d'accord s'il ne s'agit que de l'état de régime, encore pourrait-il y avoir, en deuxième ordre, un effet sur les amplitudes; mais si nous considérons le phénomène transitoire, les relations seraient sans doute plus compliquées.

Un membre de la Commission. — Ne pourrait-on rattacher les variations de fréquence que l'on observe au phénomène de Döppler?

M. le Président. — Sans doute, mais il conviendrait alors de donner à l'expression « phénomène de Döppler » un sens assez large. Par exemple, si la source et la station d'observation sont toutes les deux fixes, mais qu'un miroir se déplace perpendiculairement à sa surface, cela revient à faire déplacer l'image de la source ou de la station dans ce miroir; on est donc là tout près du phénomène de Döppler. En généralisant, on peut continuer à se servir du même nom lorsque le miroir a un mouvement quelconque et même quand le « miroir » est une couche ionisée dont le coefficient d'absorption est variable; mais nous sommes alors assez loin du phénomène primitif.

Ing. Le Corbeillier. — Je suis bien d'accord avec ce qu'a dit tout à l'heure M. le Prof^r Appleton au sujet des variations longitudinales. C'est ainsi que dans le problème des pavillons de hauts-parleurs de section variable, ou celui, exactement équivalent, d'une ligne électrique dont les « constantes » linéiques L et C varient d'un point à un autre, le produit LC restant constant, on trouve qu'il y a entre l'entrée et la sortie des différences à la fois de phase et d'amplitude en fonction de la fréquence; mais la fréquence est strictement conservée. Les variations des propriétés du milieu, lorsqu'elles sont longitudinales, conservent donc bien la fréquence.

M. le Président. — Il en est bien ainsi dans les cas que vient de citer M. Le Corbeiller, mais je crois que le problème réel de la propagation, même simplifié, est beaucoup plus difficile. Il faudrait considérer, en effet, que la section du pavillon, ou le L de la ligne, ont en un point donné, autour d'une valeur moyenne déterminée, de petites variations fonction du temps. L'équation différentielle, sans cesser d'être linéaire, aurait alors un coefficient au moins fonction de la variable temps, et vous savez que dans ces conditions la fréquence d'entrée n'est pas conservée.

Prof^r Appleton et *Ing. Le Corbeiller.* — C'est très exact.

Prof. Kennelly. — Concerning the study of the speed of propagation in the ionized layer, it seems to me that at the experimental point of view, there are two methods to use : first the method of interference between two wave trains having followed two different paths, and second the method using echos. Perhaps the conditions are not alike in the two cases and new properties could be found by the study of the differences between the two methods.

Prof^r Mesny. — M. le Président a demandé que nous tenions compte de la pratique, à ce point de vue les phénomènes transitoires ont une importance considérable. Les expériences de Rukop ont montré que pendant la propagation il se produit parfois des variations dans la forme du rayon joignant l'émetteur ou récepteur, cela entraîne des variations de la longueur du chemin parcouru et par conséquent des variations momentanées des fréquences se traduisant à la réception par des variations de la note de battement qui sera instable, ce qui occasionnera une gêne pour la mesure de la fréquence. Il nous a semblé que de telles variations se produisent effectivement. Il doit d'ailleurs être bien entendu qu'il s'agit là de phénomènes transitoires, qui méritent donc d'être étudiés.

M. le Président. — L'heure s'avance et je serais heureux d'entendre discuter le problème dans le cas des variations transversales.

Prof^r Mesny. — Si je comprends bien la pensée de M. le Président il s'agissait jusqu'ici du problème dans lequel le chemin géométrique peut être considéré comme invariable; nous envisagerions maintenant le cas où les petites variations des propriétés du milieu auraient pour effet de déformer le chemin. Ce problème est celui-là même auquel se rapportent les observations que je faisais à l'instant. Il me paraît d'une grande difficulté analytique, mais il serait important d'en avoir une solution au moins dans un cas particulier.

Il faut d'ailleurs distinguer entre les variations lentes du type des variations diurnes, et celles très rapides qui ont été observées et qui peuvent provenir par exemple de l'arrivée soudaine d'un nuage d'électrons. Ces variations rapides mettraient sans doute en jeu la technique mathématique des phénomènes transitoires.

Prof^r Manneback. — On peut se demander en outre si les phénomènes transitoires du début et de la fin d'un signal, ne jouent aucun rôle dans la propagation des ondes électriques. Dans la propagation le long des fils, ces phénomènes ont d'autant plus d'importance que la ligne est plus longue, les pertes plus grandes et la fréquence plus basse. Dans l'atmosphère, les distances sont grandes, les pertes par absorption semblent relativement faibles et la fréquence des ondes est élevée. Les phénomènes transitoires ne paraissent donc pas avoir de l'importance dans la question qui nous occupe.

Le long des lignes, les phénomènes transitoires ont généralement pour effet de modifier l'amplitude, la phase et même la fréquence des signaux. On pourrait ainsi s'attendre à une altération de la modulation et même de la fréquence au début et à la fin d'un signal transmis par ondes électriques. Cet effet paraît négligeable, sauf peut-être le cas où le phénomène transitoire ne se trouverait pas dans l'émetteur mais bien dans le milieu même de propagation; par exemple, si la densité des électrons libres dans la haute atmosphère était sujette à des variations incessantes et rapides.

Ing^r Le Corbeiller. — Je crois qu'il faut distinguer les phénomènes transitoires que l'on observerait à l'arrivée, même si les propriétés du milieu ne varient pas, du fait que le milieu est dispersif; et ceux qui peuvent provenir de la variation des propriétés du milieu en fonction du temps. Enfin, le signal lui-même comporte pratiquement au début et à la fin, une période transitoire.

M. le Président. — Je voudrais passer maintenant à une question à laquelle nous a fait penser la communication du Commandant Mesny : c'est l'étude de ce qui se passe réellement lorsque des ondes progressives se déploient le long d'un conducteur et arrivent à l'extrémité du conducteur.

Le problème est d'un intérêt actuel, en raison des formes d'antennes qu'on a montées récemment en France. On admet actuellement pour les besoins de la pratique que la vitesse de propagation le long d'un fil est indépendante de sa forme; elle est la même si le conducteur est rectiligne ou s'il fait un angle.

Certains se sont demandé ce qui se passait à l'extrémité d'une antenne verticale et si l'antenne quart d'onde est bien celle dont l'onde propre est égale à 4 fois la longueur de l'antenne.

Prof^r Manneback. — Il y a longtemps que les expérimentateurs ont signalé que la distance entre l'extrémité libre d'un oscillateur linéaire (par exemple les fils de Lecher), et le premier nœud de courant est légèrement inférieure à un quart de longueur d'onde (« end effect »). Cela revient à dire que la distribution du courant et de la tension le long d'un oscillateur linéaire n'est pas exactement sinusoïdale et que le champ électromagnétique dans le voisinage de l'oscillateur ne constitue pas rigoureusement un système d'ondes stationnaires. Il doit d'ailleurs en être ainsi, sinon l'oscillateur ne rayonnerait pas d'énergie.

La question théorique qui se pose et, à notre connaissance, n'a pas encore été résolue, est de préciser le lien qui existe entre la distribution du courant sur une antenne et le mécanisme du rayonnement dans son voisinage. A grande distance, comme on sait, le rayonnement s'obtient très approximativement en admettant une distribution sinusoïdale du courant sur l'antenne.

M. le Président. — Je remercie M. le Professeur Manneback pour l'exposé qu'il vient de donner du problème, nous espérons qu'il pourra le résoudre et qu'il publiera sa solution.

J'aurais voulu aussi inscrire au programme le problème intéressant des démultiplicateurs de fréquence, mais vu l'heure avancée, je le signale à votre attention pour la prochaine Assemblée Générale.

La séance est levée à 16 h. 25.

ANNEXES

ANNEXE I.

REPORT TO COMMISSION I ON RADIO FREQENCY STANDARDS AND MEASUREMENTS

by Dr. D. W. DYE, F. R. S.

(National Physical Laboratory.)

The general position regarding radio-frequency standards and measurements shows steady progress in various directions, but there is not a great deal of published matter falling within the scope of the Commission which has not already been referred to in the previous report to the Commission.

The work carried on at the laboratory has included the maintenance of the tuning fork controlled multivibrator wavemeter together with the auxiliary apparatus necessary to the accurate measurement of frequencies up to 60,000 kilocycles per second. A regular service of transmissions at sixteen different wave-lengths has been maintained and has been received satisfactorily not only in England, but also in various parts of Europe, in spite of the smallness of the radiated power.

A temperature-controlled piezo-electric oscillator circulated from one national laboratory to another at the instigation of the Bureau of Standards was measured at the Laboratory and a report embodying all the measurements made in its journey out from and back to the Bureau of Standards has been received. The more complete details of the comparison will doubtless be communicated in the corresponding report from the B. S., but it will suffice to state here that all the measurements indicate a mean divergence from the mean of only three parts in 10^5, since this mean uncertainty includes the uncertainties of measurement at two laboratories and the uncertainty of frequency of the oscillator. The agreement may be considered very satisfactory, and would appear to indicate that the more important national laboratories can measure radio-frequency directly in terms of the unit of time to an inaccuracy no greater than the variability of any actual radio frequency standard.

The second of an earlier type of piezo-oscillator originally circulated from the B. S. was also measured, and at the same time measurements were made upon a series of vacuum mounted quartz resonators of the Giebe type, which were forwarded to the National Physical Laboratory with the American piezo-oscillator.

All these measurements also confirm the conclusion that radio-frequency measurement is in a very satisfactory condition, such that given a suitably steady radio frequency source of any kind its frequency can be measured to an accuracy of one or two parts in a hundred thousand without reference to any actual standard of radio-frequency.

The very great usefulness of quartz piezo-oscillators both as standards and for frequency control continues to attract considerable attention. At the National Physical Laboratory the work has been partly theoretical and partly

experimental. A fairly complete résumé of all the most important works on piezo-electric properties is in an advanced state of preparation and should prove of considerable value. The work can never be complete, but has been brought to include work done up till the end of 1927.

Theoretical studies of the relationships between the electric and the dynamic properties and the equivalent network constants of resonators have been made, and a paper has been written on the subject. A theoretical solution to the mathematical case of the quartz oscillator and its associated electrical network has also been worked out, but has not been experimentally followed yet. On the experimental side much work has been done upon the development and use of an interference method for the examination of the modes of vibration of plate-formed crystals of various shapes and thicknesses. Demonstrations of the arrangement have been given, and a preliminary short paper is in course of preparation on the results obtained and on the possibilities of the method for further work. Numerous observations made on discs and rectangular plates of various dimensions have thrown much light upon the nature of the vibrations which occur. It has been found, for example, that the vibrations are nearly always complex, and usually consist of mixed longitudinal and flexural modes about axes which are inclined at various angles according to the various dimensions of the plate. The longitudinal vibrations are also not simple in the case of that mode corresponding to the thickness of a plate, but are made up of a simple translational vibration upon which is superposed a complicated pulsational mode producing standing waves on the surface.

The work is illuminating the problem of the nature of the vibrations which can occur and is being actively pursued. The application of the piezo-electric crystal oscillator to the needs of various services has resulted in numerous circuit arrangements being devised to which the crysals are applied in various ways to secure power without undue risk of breakage and with independence of circuit and battery variations.

It cannot be said, however, that the use of such crystal control has grown at such a rapid rate as might have been anticipated. There are, no doubt, drawbacks to the use of crystal control on account of the presence of two or more modes of vibration near together, so that either may be maintained, and sometimes the mode changes from one kind to another merely by change of temperature, thus giving a discontinuity which is very undesirable. These defects of the majority of thin plates will doubtless be overcome when knowledge has been gained about the causes of the very mixed vibrations usually occurring in them.

The alternative uses of magneto striction oscillators and of harmonic multiplication from lower frequencies is also receiving some attention, but no information is yet available on these methods of realising accurate and constant radio frequency.

Further work on the international measurements of frequency of short wave stations has not proceeded very far yet, but will doubtless develop further quite soon now. The suggestion made at the Washington Conference to carry out measurements upon the short wave Naval station at Arlington should soon be capable of demonstration as to suitability now that the station has inaugurated its time service. The measurements will be attempted at the Laboratory shortly. In this connection it may be possible to obtain information regarding quick variations in the path of travel of the waves by observation of the fluctuations in frequency of the beat tone produced by interference with a perfectly steady local source. One of the difficulties in such work internationally is to secure strict simultaneity of observations.

There are now a considerable number of beam stations in existence in various parts of the world which could be used to advantage for the purpose of international comparison and for the object mentioned above as well as for the unification of the frame of reference so that they all fit into their intended places in the spectrum of frequency.

CURRENT MEASUREMENT.

Some advances have been made towards the establishment of a basis of measurement of current at very high radio frequencies by Moullin. The method has not yet been published, but a demonstration of the apparatus has been given and a very short account of it given in « Experimental Wireless » of August 1928. The principle of the instrument is the attraction between two straight parallel conductors, one of which is fixed and the other moving. The principles of design and construction are such that all corrections can be calculated. The ammeter is suitable as a standard for currents of the order of 2 amperes and for frequencies up to 20,000 kilocycles per second. Intercomparison between various possible methods of measuring extra high frequency currents should now be made. There are current transformer, condenser subdividing and electrodynamic methods available, but these have not been compared to the writer's knowledge, and much useful information would be gained by a carefully made series of tests at various frequencies.

INDUCTANCE AND CAPACITY.

It was felt that some international comparisons of inductance and capacity should be made, and arrangements were accordingly made for the Bureau of Standards to send a subdivided condenser to the National Physical Laboratory, whilst the National Physical Laboratory undertook to send some fixed inductance standards to the Bureau of Standards. These proposals have been set on foot and the condenser has been received from the Bureau; the results of these comparison measurements will not be known till a later date. The measurements form the commencement of a regular series of such interchanges, and it is proposed to recommend other countries to partake in such measurements if that is thought desirable.

APPLIED MEASUREMENTS. — MEASUREMENT OF SIGNAL INTENSITY.

Advances have been made in the methods of measurement of received signal intensity, so that it now becomes possible in favourable cases to separate the two components in a received wave and to measure the phase angle between them. Such measurements should now be called received wave analysis measurements.

The principles of the method now in use have been described by Hollingworth, « Journal of Scientific Instruments », January 1928. Briefly, the operations consist in measuring the intensity in two coils oriented at 45° on each side of the geographical plane of propagation. The phase angle between these electromotive forces is also measured. The results obtained have confirmed previous results derived from previous less accurate observations, and have brought to light further interesting phenomena. Preliminary results are given in a recent publication (Proc. Roy. Soc. A, June 1928). There seems no doubt that these more elaborate measurements will be fully justified and merit consideration by any other nationalities who may wish to participate in similar measurements.

In the field of short wave measurements, work is in progress along similar lines to those for the longer waves. The range of wavelengths is from 25 to 65 metres. At these very short waves, owing to the rapid variations which occur, the necessary observations must be made simultaneously, which involves a design quite different from that developed for long waves.

Other radio frequency measurements of indirect bearing on the more scientific aspect of the standards have been the development of a radio frequency bridge by which accurate measurements of the power factor and permittivity of insulating materials and of any capacity in general may be measured. The bridge may be used for the measurement of inductance also and for the determination of the impedances of internal valve circuits at radio frequencies up to 1,500 kilocycles per second. There seems little doubt that such methods in such measurements will ultimately displace all others on account of increased accuracy, greater speed and freedom from the necessity of great steadiness in the source of radio frequency.

Bridges have also been developed for the measurement of the various impedances of valves and of their mutual conductances at telephonic frequencies. These are indirectly of value in radio frequency measurements. The uses of beat tone generators as sources of variable telephonic frequency are also becoming more common on account of long range conveniently adjustable, purity of wave form and independence of the output load. These, though not directly concerned in radio frequency standards and measurements, are nevertheless of importance in connection with the measurement of those quantities such as capacity, inductance and effective resistance, which are themselves directly used in radio frequency measurements.

August 20, 1928.

ANNEXE II.

REPORT OF THE CHAIRMAN OF THE COMMISSION ON RADIO WAVE PROPAGATION

by L. W. AUSTIN,
Bureau of Standards.

As it is less than a year since the meeting of the General Assembly of the Union in Washington, the amount of material to be presented by the Commission on Radio Wave Propagation at this meeting is considerably less than that presented in 1927.

However, during the past year a number of important papers have been published which mark a very definite advance in our knowledge of wave propagation.

STUDY OF DOWNCOMING WAVES.

In England, Appleton and Ratcliffe (1) (¹) have carried on experiments in Peterborough on signals from London (about 80 miles distant) at a wave length of about 400 m. In a portion of the experiments, the receiving apparatus was rapidly shifted between an antenna and loop while at the same time the wave length at the transmitting station was continuously changed back and forth by about 10 m. in order to procure definite phase relations, the change being repeated six times in twenty seconds. The photographic records of reception show that the angle of incidence of the downcoming wave varied very rapidly. In one case, two hours before sunrise the sine of the angle changed from 0.6 to 0.46 in 40 seconds. Such rapid changes can hardly be due to changes in the height of the Kennelly-Heaviside layer, but as the authors suggest, may be due to reflections from an uneven surface. In another part of their experiments, Appleton and Ratcliffe made use of the well-known loop and antenna unidirectional system. This system is balanced so as to receive no signal from a certain station when no downcoming wave is present, and can be used to measure the downcoming wave when it appears.

With this apparatus it was found that after a balance had been obtained in the daytime, large deflections in the galvanometer of the receiving apparatus were observed near sunset and that their amplitude increased as the night advanced. During the day the balance of the unidirectional system remained nearly constant, indicating either no downcoming wave or one of very constant angle.

When comparisons were made of reception on an antenna with that on a loop, it was found that most of the variations were proportional on the loop and antenna. This indicated that these variations were not due to a change of angle but rather to a change of intensity. Changes in phase were also found to occur but were of less importance than the intensity changes of the downcoming waves. A comparison of the abnormally polarized wave with the vertically polarized wave indicated that they were not separate waves but were components of one which was elliptically polarized.

Appleton and Ratcliffe (2) in another paper have determined the sense of rotation of the polarization of the downcoming wave, for a wave length of about 400 m., experiments being made both with south-north and west-east transmission. In these experiments, signals were received in succession on three loops, 45° apart

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(¹) P. 40.

with the central loop pointed toward the transmitting station. In order to get a sufficient number of equations for the determination of all the variables, it was necessary to produce continuous slight changes in the wave length of the transmitting station. The resulting oscillograph curves of the reception showed that the downcoming wave was in general elliptically polarized and that the sense of rotation is left-hander. This supports the supposition that the carriers in the upper atmosphere involved in the refraction are electrons, acted upon by the earth's magnetic field.

J. Hollingworth (3) in England, working with wave lengths of 10,000 m. or more and at distances of 400-1,000 km., reports the following : 1° During the night long-wave signals are moderately steady in intensity but with much abnormal polarization; 2° Before sunrise, when the sun reaches a point 7° below the horizon for a point midway between the transmitting and receiving stations, the conditions of polarization begin to change and the abnormal polarization decreases. This change seems to take place in two steps, the first of which, lasting about 12 minutes, is very definite. Similar effects with increasing polarization take place about sunset; 3° During the day the reflection coefficient of the downcoming wave is generally about 30 % of its night value though at times it falls to zero; 4° Hollingworth holds that it is probable that the changes in height of the Kennelly-Heaviside layer, between night and day are slight. He also holds that absorption of the downcoming wave in the region below the refracting layer is responsible for a large share of the observed variations in intensity; 5° For distances below 400 km. the daylight reflection coefficient is usually zero but at times rises to 0.4; 6° The downcoming wave always appears to be abnormally polarized both day and night, but no marked changes are observed at sunrise or sunset; 7° The effective height of penetration of the wave in the upper atmosphere appears to be about 150 km.

Observations at the Bureau of Standards in Washington, which are based on approximately 200 continuous recorder records of the reception of long-wave signals from distances less than 700 km. on an antenna and on a loop, and also numerous observations on a unidirectional circuit support the view that most of the changes in intensity in radio signals, especially in summer, are due to absorption rather than to a change in the angle of the downcoming wave. Changes in angle, when present, more commonly occur in the cooler months and often with very large and rapid variations, sometimes even, indicating a wave coming down from the back. This can be explained either by reflection from an irregular surface or by refraction in a medium of very unevenly distributed ionization. The coupling balance of the unidirectional circuit varies from time to time, indicating changes in the angle of the downcoming wave even in the daytime, although during the warmer months it seems at times to remain constant both night and day for considerable periods.

Dr. A. H. Taylor and Mr. L. T. Young (4) of the Naval Research Laboratory, Bellevue, D. C., have observed some very curious effects in connection with the so-called echo signals. In looking for round-the-world signals from Rocky Point, L. I. ($f = 20,000$ kc.) distant about 430 km from Washington, they noticed what appeared to be retarded signals which had reached Washington by some shorter path than the great circle distance round the world. An entirely satisfactory explanation of this phenomenon has not been found. Taylor and Young have tentatively suggested either a reflection from the heavily ionized region near the magnetic pole, or scattered back reflections from mountainous regions in the zones of reception beyond the skip distance region. These observations perhaps indicate that the absence of skip distance, noticed by Capt. Staut in Senegal, which has been confirmed by commercial operators in tropical Africa, may be a similar phenomenon.

CORRELATION OF RADIO TRANSMISSION WITH OTHER NATURAL PHENOMENA.

Temperature and Barometric Pressure. — G. W. Pickard (5), in America, has carried out experiments of night reception in the broadcasting range which indicate that signal strength is directly related to temperature, maximum reception being associated with maximum temperature and vice versa. This is the reverse of the observations of Austin and Wymore, who found that for long-wave day signals, coming from moderate distances, falling temperature improved the reception. In this connection it may be noted that solar activity and magnetic storms also produce opposite effects on radio transmission at night and in the daytime. In Mr. Pickard's work, near Boston, the transmission was from Chicago 1,400 km. distant. In this case it was found that the temperature in Boston was far more important than the Chicago temperature or the average temperature along the transmission path.

A correlation was also found between reception and barometric pressure, the signal strength increasing when the low pressure areas passed the receiving point, and decreasing at the time of high pressure.

Solar Activity and Magnetic Storms. — C. N. Anderson (6) of the American Telephone & Telegraph Company, has given an extended discussion of the whole subject of the correlation between solar activity, terrestrial magnetism, earth currents, and radio transmission, in which he makes a special study of the signal measurements of the A. T. and T. in connection with the establishment of the transatlantic telephone service. From these observations he concludes that, while there is an unmistakable correlation between these phenomena in the broad movements corresponding to the 11-year solar cycle, yet in the deviations from this broad trend the correlation is small.

DIRECTION VARIATIONS OF RADIO SIGNALS.

R. L. Smith-Rose and S. R. Chapman (7) in England have published a study of the apparent direction variations of rotating beacon transmitters.

They find that night errors in bearings obtained from a radio beacon are often very large when the signals are received on a loop but are very much reduced in the case of reception on a vertical antenna. This is of course to be explained from the fact that a vertical antenna does not respond to horizontally polarized waves, and is in agreement with the results obtained at the Bureau of Standards when a vertical rod is used as an antenna on an airplane in connection with a cross coil beacon.

H. T. Friis (8), in America, has carried on interesting directional experiments on 16 m., transatlantic signals. His method depends upon the beat effect of two received signals, one from a local source and one from a distant station, received on two spaced receivers with their respective antennas. The beat note outputs of the two receivers are connected to the deflection electrodes of a Braun cathode ray oscillograph so that the resulting figure shows the phase difference at the two receiving points. By placing the two receivers a third of a wave length apart at right angles to the direction of propagation, direction variations in the horizontal plane can be observed; while by placing the two in the direction of propagation, the vertical angle can be measured. Variations amounting to 30° in the horizontal angle were noted, and at times the vertical angle varied from 0° to 60°.

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ANNEXE III.

COMMISSION III.

REPORT OF THE MEETING OF THE SUB-COMMITTEE HELD ON WEDNESDAY, 12th SEPTEMBER 1928.

by L. W. AUSTIN.

Present : Messrs. Bureau, Kennelly, Parkinson, Snyder, Watson Watt.

The Sub-committee recommends to the Commission :

a) That the general study of the distribution in the radio spectrum of the energy of atmospheric disturbance should be undertaken forthwith.

b) That the quantity to be measured should be the mean field strength, expressed in microvolts per metre, of the atmosphere within specified frequency bands, the mean to be measured over a period of time to be specified. The field strength should be referred to that electromotive force of the mid-frequency of the frequency band, introduced from a local source into the antenna circuit, which gives the same deflection of the ultimate recording instrument.

c) That the apparatus used in all countries for this measurement should be vigorously identical, and that the identical aerials used should be symmetrics T-antennas of a single wire, 50 m. long and 20 m. high with a coupling resistance of 20,000 ohms.

d) That the detailed design and specification of a recordy apparatus to operate simultaneous on six·frequency bands should be prepared by Messrs. Snyder and Watson Watt.

e) That the frequency bands first explored should lie between 1,000 kc. and 20 kc. but that the apparatus should be capable of operating on 20,000 kc. and that recording in the higher frequency bands should be regarded as of extreme urgency.

f) That a constant band width of 25 cycles is desirable throughout the installations.

g) That the generous offer, conveyed by M. Snyder, that the General Electric Company of America will provide, free of cost to the U. R. S. I. and its constituent National Committees, the installations required for these measurements, should be accepted, and, that the thanks of the Commission for this undertaking should be recorded.

Bruxelles. — Imp. Hayez, rue de Louvain, 112.

Mai-Juin 1931 VOL. III May-June 1931

Union Radio Scientifique Internationale

International Scientific Radio Union

PALAIS DES ACADÉMIES, BRUXELLES

Secrétariat Général : 54, avenue des Arts, Bruxelles

Recueil des Travaux de l'Assemblée Générale tenue à Copenhague en Mai-Juin 1931

Papers of the General Assembly held in Copenhague in May-June 1931

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INTRODUCTION

L'Assemblée Générale de l'U. R. S. I., tenue en mai-juin 1931 à Copenhague, comportait, outre l'Assemblée Générale proprement dite, des séances des cinq Commissions de l'U. R. S. I. et des séances publiques.

Les séances plénières ainsi que les séances publiques furent présidées par M. le Général Ferrié, Président de l'U. R. S. I.

Les délégués officiels des pays adhérents étaient les suivants :

Belgique : MM. l'Ingénieur R. BRAILLARD, le Profr E. DIVOIRE, le Dr R.-B. GOLDSCHMIDT, le Profr CH. MANNEBACK et l'Ingénieur J. MARIQUE ;

Danemark : MM. l'Ingénieur K. CHRISTIANSEN, le Profr KNUDSEN, le Profr LA COUR, le Profr A. LARSEN, le Profr Dr P. O. PEDERSEN, le Dr V. POULSEN et l'Ingénieur SCHOU ;

Etats-Unis d'Amérique : MM. le Dr L. W. AUSTIN, L. A. BRIGGS, le Profr Dr CHAFFEE, le Dr J. H. DELLINGER, le Major-Général G. O. SQUIER et le Dr W. WILSON ;

France : MM. le Général G. FERRIE, P. BRENOT, le Commandant R. BUREAU, le Profr R. JOUAUST, le Colonel L. JULIEN, l'Ingénieur M. LATOUR, l'Ingénieur LE CORBEILLER, le Profr R. MESNY et l'Ingénieur E. PICAULT ;

Grande-Bretagne : MM. le Profr E. V. APPLETON, le Profr S. CHAPMAN, le Dr D. W. DYE, le Dr R. L. SMITH-ROSE, le Dr E. H. RAYNER et le Dr R. A. WATSON-WATT ;

Italie : MM. le Lieutenant-Colonel F. AMOROSO, l'Ingénieur C. BACCHINI, le Commandant Ingénieur T. GORIO, le Major Chevalier A. MARINO et le Commandant Chevalier U. RUELLE ;

Japon : MM. le Capitaine M. HATTORI, l'Ingénieur Y. ITOW, l'Ingénieur Y. KUSUNOSE, le Dr H. NAGAOKA, l'Ingénieur T. NAKAGAMI et le Lieutenant-Commandant TANI;

Pays-Bas : MM. A. DUBOIS et le Dr B. VAN DER POL;

Suède : M. le Profr PLEYEL;

Suisse : M. le Dr Ingénieur LUGEON.

L'Allemagne n'était pas représentée officiellement à l'Assemblée, mais M. le Professeur Dr K. W. Wagner y représentait les milieux scientifiques allemands.

Le *Secrétariat Général* était représenté par M. le Dr R. B. Goldschmidt, Secrétaire Général et le Capitaine Dorsimont.

Séance inaugurale du lundi 28 mai 1931

Opening Session, Thursday, May 28, 1931

M. le Profr P. O. PEDERSEN ouvre la session et prononce l'allocution suivante :

MONSIEUR LE PRÉSIDENT, MESSIEURS,

J'ai l'honneur, au nom du Comité Danois, de souhaiter à tous les membres de l'Union Radio-Scientifique Internationale une très cordiale bienvenue.

Le nombre et l'étendue des réunions internationales a été en augmentant continuellement pendant ces dernières années et cet essor a été considéré de bien des côtés avec un peu de scepticisme qui n'est peut-être pas entièrement injustifié. Toutefois, en ce qui nous concerne, le cas est clair et net : les problèmes mêmes dont nous nous occupons, comme par exemple la propagation des ondes radio-électriques, ne peuvent absolument pas être résolus nationalement, mais exigent, vu leur nature, une collaboration internationale. Je serais même tenté de dire qu'il serait désirable que nous entraînions dans cette collaboration quelques-unes des autres planètes, mais, malheureusement, je crois que nos chances sont minimes sur ce point. J'ose en tout cas espérer que les nations qui ne se sont pas encore ralliées à notre Union le feront sans trop tarder.

Pour terminer, j'exprime des vœux ardents pour que l'Assemblée de l'U. R. S. I., qui nous réunit aujourd'hui, puisse encore marquer à son actif une somme importante de travail utile et fécond pour la radiotechnique.

Enfin, j'ai l'agréable devoir de prier notre Président célèbre, M. le Général Ferrié, de vouloir bien accepter, dès maintenant, la présidence de cette réunion.

M. le Président répond aux souhaits de bienvenue qui lui sont exprimés et dit combien tous les assistants sont heureux d'être réunis à Copenhague sous la présidence d'un savant éminent tel que le Prof^r^ Pedersen et avec le concours du célèbre Prof^r^ Poulsen. Il faut remarquer que la tâche imposée à l'U. R. S. I. est particulièrement difficile attendu qu'elle s'adresse à des phénomènes fugitifs et sans cesse variables qui exigent, pour être observés, une collaboration internationale.

Il cite l'exemple de la recherche par Schwabe de la périodicité des phénomènes solaires et espère qu'avec les méthodes scientifiques actuelles et la coopération mondiale, la recherche des périodes de variation des phénomènes de la radiotechnique donnera plus rapidement des résultats satisfaisants.

Il passe ensuite la parole au Secrétaire Général, M. le D^r^ R. GOLDSCHMIDT, et le prie de donner lecture de son rapport.

RAPPORT DU SECRÉTAIRE GÉNÉRAL SUR L'ACTIVITÉ DE L'U. R. S. I. DE 1928 A 1931.

REPORT OF THE GENERAL SECRETARY ON THE ACTIVITY OF THE U. R. S. I. FROM 1928 TO 1931.

Depuis l'Assemblée Générale qui s'est tenue à Bruxelles en septembre 1928, l'U. R. S. I. a continué à déployer une grande activité, ainsi qu'il ressort du nombre et de la valeur scientifique des rapports et des travaux dont le Secrétariat Général a été saisi et qu'il a mis en circulation (¹).

Pays adhérents. — Lors de l'Assemblée Générale de 1928, le nombre de pays adhérents était de 11, à savoir : AUSTRALIE, BELGIQUE, ÉTATS-UNIS, FRANCE, GRANDE-BRETAGNE, ITALIE, JAPON, NORVÈGE, PAYS-BAS, PORTUGAL, UNION SUD-AFRICAINE.

Quatre nouveaux Comités Nationaux ont été constitués depuis dans le cadre des statuts prévus par le Conseil International de Recherches, et nous avons été heureux de pouvoir notifier leur adhésion en attendant que celle-ci soit ratifiée par le Comité Exécutif.

Les nouveaux pays adhérents sont : le DANEMARK, la NOUVELLE-ZÉLANDE, la SUISSE et la SUÈDE. Je suis certainement votre interprète en saluant et en souhaitant la bienvenue aux délégués de ces Comités.

Nous avons eu, par contre, à déplorer l'élimination d'un Comité National dont la collaboration nous avait toujours été précieuse, le Comité National Australien, qui a été dissout en raison des difficultés financières considérables que rencontre actuellement ce pays. Convaincus d'avoir, ici encore, été vos interprètes, nous avons transmis aux éminentes personnalités qui composaient ce Comité National, les vifs regrets que l'U. R. S. I. ressent en perdant leur collaboration et nous les avons assurées que lorsque, par suite de circonstances nouvelles, le Comité National Australien pourra être reconstitué, notre Union sera heureuse de renouer des relations auxquelles elle attachait le plus grand prix.

Nous vous proposons, par mesure exceptionnelle, de continuer en faveur des membres du Comité National Australien, et à titre personnel, la communication des documents et des correspondances générales de l'U. R. S. I. En agissant ainsi, non seulement nous marquerons aux savants australiens l'importance que nous attachons à leur appui, mais nous faciliterons, en même temps, la reprise effective d'une collaboration internationale avec eux lorsque les circonstances se présenteront plus favorablement.

Quoiqu'il en soit, la progression du nombre de Comités Nationaux affiliés à notre Union témoigne de l'intérêt qui se rattache à ses travaux et constitue un encouragement en faveur de leur pousuite et de leur développement.

Le Secrétariat Général continue, d'autre part, par les négociations déjà entamées à Washington en vue d'obtenir d'autres adhésions.

(¹) Annexe I, p. 7.

Réunions tenues par l'U. R. S. I. depuis 1928. — L'U. R. S. I. a participé effectivement aux travaux du Comité Consultatif International Technique des Communications Radioélectriques (C. C. I. R.) qui s'est réuni à La Haye en septembre 1929. Grâce à l'aimable intervention de nos collègues du Comité National Néerlandais, notre Union a pu être représentée à La Haye par une délégation composée de notre Président, M. le Général Ferrié, et de votre Secrétaire Général, ainsi que de plusieurs personnalités appartenant aux différents Comités Nationaux et au Secrétariat Général.

Plusieurs membres de la Commission financière s'étant trouvés réunis à cette occasion, celle-ci a pu procéder à des délibérations dont le compte-rendu a été envoyé aux différents Comités Nationaux.

En août dernier, grâce à l'initiative de M. le Prof^r^ Kennelly, Président de la IV^e^ Commission, celle-ci a tenu à Stockholm, à l'occasion de la IV^e^ Assemblée Générale de l'Union Géodésique et Géophysique Internationale, une réunion fructueuse dont vous avez eu également les comptes-rendus.

Selon les décisions prises à Bruxelles en 1928, une Assemblée Générale devait être tenue en septembre 1930; les réunions auraient eu lieu partiellement en Belgique et partiellement en Hollande. Des circonstances ultérieures, au sujet desquelles les membres du Comité Exécutif ont été consultés, ont amené celui-ci à postposer de huit mois cette Assemblée, à laquelle plusieurs de nos éminents collègues eussent été empêchés de se rendre.

Bibliographie. — Ainsi qu'il résulte d'un rapport spécial (¹), l'étude du développement des services de bibliographie a été poursuivie.

L'envoi des références bibliographiques fournies par les Comités Nationaux a été effectué régulièrement.

Nous devons remercier de leur précieux apport, ceux de ces Comités qui ont bien voulu consacrer un soin tout particulier à nous documenter.

Travaux des Commissions. — Un travail international, d'une importance considérable, s'est poursuivi au sein des différentes Commissions. Vous noterez notamment, avec une satisfaction particulière, l'organisation, aujourd'hui acquise, de l'envoi des « Ursigrammes ». De tels résultats donnent la mesure de l'importance d'un organisme comme le nôtre et évoquent les réalisations qu'il est encore susceptible de fournir dans l'avenir.

Nous devons témoigner aux Présidents des Commissions ainsi qu'aux Membres de celles-ci, notre très vive reconnaissance pour le dévouement qu'ils ont montré en apportant à ces travaux le concours de leur science si profonde et si hautement estimée.

Par application des décisions prises à Bruxelles, en 1928, les Commissions ont été reconstituées et vous avez pu apprécier la valeur des concours qui leur ont été apportés. Les listes indiquant la constitution de ces Commissions vous ont été communiquées.

Les travaux des Commissions faisant l'objet de rapports spéciaux, il ne nous paraît pas nécessaire d'en faire, ici, la relation.

Relations avec d'autres organismes scientifiques. — Il y a lieu de signaler :

Les travaux relatifs à l'éclipse du 9 mai 1929, qui ont fait l'objet de diverses communications;

La participation de l'U. R. S. I. aux travaux de la Commission Internationale de l'Année Polaire de 1932-1933. Cette question sera examinée par la présente Assemblée;

Les relations de l'U. R. S. I. avec l'Union Internationale de Géodésie et de Géophysique;

Celles avec l'Union Internationale d'Astronomie et en particulier avec la Commission des Relations entre les Phénomènes solaires et terrestres; l'Assemblée aura notamment à ratifier la désignation de notre Président, comme représentant de notre Union au sein de cette Commission.

Nouveaux statuts de l'U. R. S. I. — Les statuts de l'Union avaient été remaniés à l'occasion de l'Assemblée Générale de 1928; le projet de texte communiqué à tous les Comités Nationaux ainsi qu'au Conseil International de Recherches, n'a fait l'objet d'aucune observation. Néanmoins,

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(¹) Annexe II, p. 9.

nous vous prierons de bien vouloir ne pas considérer ce texte comme définitivement adopté, le Conseil International de Recherches élaborant de nouveaux statuts pour le mois de juillet prochain.

Cependant, en raison de l'orientation nouvelle dans laquelle nous semblons devoir nous engager pour ce qui concerne la constitution des ressources de notre Union, l'avant-dernier paragraphe de l'article 18 devra vraisemblablement être modifié, pour que la cotisation annuelle unitaire des pays corresponde aux besoins actuels.

Rapports avec le Comité Consultatif International Technique des Communications Radioélectriques (C. C. I. R.), institué par la Conférence Internationale Radiotélégraphique de Washington en 1927. — L'organisation des rapports de l'U. R. S. I. avec le C. C. I. R. est en bonne voie.

Ainsi que nous l'avons rappelé, l'U. R. S. I. a été invitée à la réunion que ce Comité a tenue à La Haye en 1929. Elle l'est encore à la réunion actuelle.

Différentes propositions avaient été introduites à La Haye en vue d'une collaboration permanente entre cet important organisme et notre Union. Ces propositions n'ont pas pu avoir de suite effective, pour des raisons qui résultent notamment de l'organisation même du C. C. I. R., qui a décidé, à La Haye, de ne pas constituer de Secrétariat permanent.

D'autre part, et en attendant que l'Administration néerlandaise puisse donner suite à son aimable intention de proposer à la Conférence Radiotélégraphique Internationale qui doit se réunir à Madrid, en 1932, d'admettre l'U. R. S. I. comme membre délibérant du C. C. I. R., notre collaboration avec cet organisme ne peut avoir qu'un caractère officieux.

Cependant, à La Haye même, des projets importants (dont vous avez reçu le texte) avaient été présentés, notamment par le Comité Français, projets qui consistaient à mettre en jeu la collaboration des Administrations et des Compagnies privées des pays adhérents à notre Union, selon un programme précis qui prévoit les renseignements à fournir par le trafic commercial normal, la participation éventuelle des postes récepteurs commerciaux à certaines observations sur la propagation, la documentation sur les atmosphériques, l'enregistrement de phénomènes divers et mesures spéciales, etc.

Les négociations relatives à cet intéressant programme sont aujourd'hui engagées par l'U. R. S. I. avec les Administrations compétentes.

Chacun reconnaît la haute utilité scientifique de ce programme, des difficultés d'ordre administratif doivent encore être résolues.

La question sera examinée par la présente Assemblée.

Publications. — Eu égard à l'intérêt exceptionnel qui s'attache aux Assemblées Générales de l'U. R. S. I., la publication des comptes-rendus de nos travaux présente une importance particulière. Le plus grand soin a toujours été apporté à leur édition. Mais il importe que les éminentes personnalités qui prennent une part effective aux délibérations, veuillent bien nous assister dans les efforts que nous faisons pour accélérer les travaux d'impression, en nous faisant parvenir, dans le plus bref délai possible, les épreuves que nous leur envoyons pour la correction.

Cette célérité est indispensable si l'on veut faire en sorte que les comptes-rendus puissent être distribués et mis à la disposition du public dans un délai convenable.

Organisation de la présente Assemblée Générale. — Il nous reste à parler de l'organisation de la présente Assemblée Générale. Je dois remercier, en premier lieu, l'Administration danoise et en particulier MM. les Directeurs Généraux Pedersen et Christiansen pour l'aide précieuse et dévouée qu'ils nous ont apportée dans sa préparation.

Sous d'aussi heureux auspices, et eu égard aux multiples facilités qui nous sont accordées pour nos travaux, ceux-ci vont se dérouler dans le milieu le plus favorable.

Je dois également renouveler aux Membres des Commissions, l'appel déjà adressé aux Présidents de celles-ci, quant à l'organisation des travaux des Commissions.

Les Commissions s'inspireront utilement de cette considération que le but des Assemblées Générales, identiques à la nôtre, n'est pas seulement de provoquer des discussions sur des sujets scientifiques qui leur auront été soumis, mais aussi et surtout de préparer des programmes de travail pour les recherches qui, sortant du cadre du laboratoire, nécessitent une collaboration internationale.

Les Commissions pourront donc, en premier lieu, examiner les programmes de travail qui leur seront soumis. Elles se pénétreront de la nécessité de prendre au sujet de ces propositions des décisions fermes et d'arriver à la rédaction d'un texte aussi précis que possible qui serait soumis à la dernière réunion de l'Assemblée Générale.

Les Commissions qui n'ont pas encore reçu de propositions pour un programme pourraient se borner, à une première réunion, à désigner un rapporteur chargé de l'établir, et laisser, en attendant, siéger les autres Commissions.

J'ai déjà demandé aux Comités Nationaux de désigner, parmi ceux de leur membres qui assistent à cette Assemblée, des remplaçants pour ceux de leurs délégués aux différentes Commissions, dont nous avons à regretter l'absence. Tous les délégués prendraient part au vote sur les propositions, mais, en cas de divergences de vues, l'Assemblée Générale pourrait encore décider à leur sujet en votant cette fois par État.

Quand les Commissions auront terminé ce travail d'organisation des études futures, qu'on pourrait qualifier de « travail administratif », elles pourront aborder les discussions scientifiques. On ne saurait trop les engager à limiter ces discussions à des sujets bien déterminés, si elles désirent qu'elle soient fructueuses.

La présentation des mémoires proprement dits et leur discussion auraient lieu uniquement pendant les séances publiques, qui seront évidemment de ce chef les plus intéressantes de notre Assemblée Générale.

MONSIEUR LE PRÉSIDENT,

Il me reste un devoir à remplir, c'est d'être l'interprète de tous les Comités Nationaux et de tous les membres de l'U. R. S. I., pour vous exprimer leurs sincères et chaleureuses félicitations à l'occasion de la suprême distinction que le Gouvernement français vous a conférée en vous nommant Général à vie.

Les éminentes personnalités qui composent notre Union ont été heureuses de voir aussi solennellement consacrée la haute estime du grand pays qui est le vôtre, envers l'un des plus distingués parmi les hommes de science dont il s'honore si légitimement.

Nul mieux que ceux qui participent à nos délibérations ne sait quelle part considérable vous est due dans la reconnaissance publique envers l'élite qui a fait progresser la science radioélectrique. De cette science, l'une des plus prodigieuses conquêtes de l'époque et dont l'humanité ne compte plus les bienfaits, vous avez été, dès l'origine, et vous en êtes aujourd'hui plus que jamais l'un des plus glorieux ouvriers.

L'U. R. S. I. qui se consacre à son étude et à son développement sur le plan international, a eu l'heureuse chance de trouver en vous le guide sûr et expérimenté qui lui était indispensable. Conscients de la dette de reconnaissance que nous avons contractée envers vous pour le concours, précieux entre tous, dont vous favorisez nos travaux, nous vous prions d'accepter aujourd'hui l'expression de notre grande gratitude et de notre respectueuse et profonde affection.

Cette médaille, œuvre d'un sculpteur de mérite, reproduit vos traits déjà rendus familiers à tous par la renommée; je vous prie, au nom de tous nos collègues, d'en accepter l'hommage, elle sera pour nous le souvenir impérissable de l'homme d'élite que nous honorons entre tous.

M. le Président remercie et dit son émotion devant ce témoignage de sympathie. Il déclare que le but principal de son activité a été durant toute sa vie, d'être de quelque utilité à la science. Il apprécie hautement les marques d'estime que lui donnent les membres de l'U. R. S. I., et exprime sa reconnaissance au Secrétaire Général.

Il souhaite ensuite la bienvenue à M. la Cour, Directeur de l'Institut Météorologique de Copenhague qui dirige les travaux de l'Année Polaire. Il se félicite de le voir parmi les membres de l'U. R. S. I.

Il propose ensuite de constituer les Comités Financier et Exécutif.

Après délibérations, ces Comités sont constitués comme suit :

COMITÉ FINANCIER.

Président :

M. le Prof^r Mesny	France.
MM. le Prof^r Divoire	Belgique.
le Prof^r Pedersen	Danemark.
le D^r J. H. Dellinger	États-Unis.
le Prof^r Appleton	Grande-Bretagne.
le Command^t A. Amoroso.	Italie.
le Prof^r Nagaoka	Japon.
le D^r B. van der Pol	Pays-Bas.
l'Ingénieur Lemoine	Suède.
le D^r J. Lugeon	Suisse.

COMITÉ EXÉCUTIF.

Président :

M. le Général Férrié	France.
MM. le Prof^r Divoire	Belgique.
le Prof^r Pedersen	Danemark.
le D^r L. W. Austin.	États-Unis.
le Prof^r Appleton	Grande-Bretagne.
l'Ingénieur Gorio	Italie.
le Prof^r Nagaoka	Japon.
le D^r B. van der Pol	Pays-Bas.
l'Ingénieur Lemoine	Suède.
le D^r J. Lugeon	Suisse.

Ces Comités se réuniront le 27 mai, respectivement à 15 et 17 heures.

M. le Président propose ensuite de nommer les Présidents des différentes Commissions pour les réunions à tenir au cours de l'Assemblée Générale.

Les propositions ci-dessous sont approuvées à l'unanimité par l'Assemblée.

Commission I. — *Méthodes de Mesures et Etalonnages :*
M. le D^r D. W. Dye.

Commission II. — *Propagation des Ondes :*
M. le D^r L. W. Austin.

Commission III. — *Perturbations Atmosphériques :*
M. le Prof^r Appleton.

Commission IV. — *Liaison avec les amateurs, opérateurs et praticiens :*
M. le D^r E. H. Rayner.

Commission V. — *Radiophysique :*
M. le D^r B. van der Pol.

Les Commissions éliront chacune un Vice-Président et un Rapporteur.

Les Commissions se réuniront les jours indiqués ci-dessous à 16 heures.

Commission I. — 29 mai.
Commission II. — 30 mai.
Commission III. — 1er juin.
Commission IV. — 2 juin.
Commission V. — 3 juin.

La réunion plénière de clôture est fixée au samedi 6 juin à 16 heures.

La séance est levée à 11 h. 45.

ANNEXE 1

LISTE DES DOCUMENTS MIS EN CIRCULATION PAR LE SECRÉTARIAT GÉNÉRAL.

LIST OF DOCUMENTS CIRCULATED BY THE GENERAL SECRETARY.

Pendant la période écoulée entre la dernière Assemblée Générale de notre Union (septembre 1928) et la fin mars 1931, le Secrétariat Général a mis environ 100 documents numérotés en circulation.

On peut les grouper comme suit :

I. — Caractéristiques et résultats des mesures des émissions U. R. S. I.

A) **Du Comité National Américain :**

Numéros 187, 203, 206, 208, 212, 218, 223, 236, 237, 238, 244, 250, 259, 272, 275, 283.

B) **Du Comité National Français :**

Numéros 188, 189, 198, 201, 205, 207, 209, 211, 213, 215, 217, 222, 224, 227, 228, 231, 232, 239, 240, 241, 242, 246, 247.

II. — Éclipse totale du soleil du 9 mai 1929 à Poulo Condore.

A) **Du Comité National Américain :**

No 219 : Observations du « U. S. Twelfth Naval District » pendant l'éclipse de soleil du 9 mai 1929.

B) **Du Comité National Français :**

No 234 : Observations relatives à la radioélectricité et à la physique du Globe faites à l'occasion de l'éclipse totale de soleil du 9 mai 1929 à Poulo Condore (Indo-Chine).

No 235 : Rapport sur les recherches relatives à la propagation à grande distance des ondes radiotélégraphiques effectuées à l'occasion de l'éclipse de soleil du 9 mai 1929, par M. R. Jouaust.

c) **Du Comité National Japonais :**

No 255 : Anomaly in the Radio Transmission during the Solar Eclipse of May 9, 1929, by H. Nagaoka.

III. — Commission pour l'étude des relations entre les phénomènes solaires et terrestres.

No 216 : Deuxième rapport de la Commission.

No 245 : Bulletin for character figures of Solar Phenomena. October/December 1929.

No 254 : Idem. January/March 1930.

No 260 : Idem. April/June 1930.

No 278 : Idem. July September 1930.

IV. — Ursigrammes.

No 266 : Cosmic data broadcasts 16 juillet-23 août 1930.

No 273 : New time and frequencies for broadcasting of cosmic data messages. Modifications apportées au document n° 266.

No 273 *bis* : Traduction du n° 273.

No 274 : Cosmic data. 5 octobre-8 novembre 1930.

No 276 : Idem. 9 au 22 novembre 1930.

No 277 : Idem. 23 novembre au 6 décembre 1930.

No 280 : Idem. 7 au 27 décembre 1930.

No 284 : Idem. 28 décembre 1930 au 17 janvier 1931.

No 285 : Idem. 18 janvier au 7 février 1930.

V. — Communications diverses.

a) **Du Comité National Américain :**

No 186 : The status of frequency Standardization, by J. H. Dellinger.

No 191 : Transatlantic Radio Transmission and Solar Activity, by Cl. N. Anderson.

No 192 : Methods for the measurement of Radio field Strengths, par C. R. Englund et H. T. Friis.

No 202 : Long wave radio receiving measurements at the Bureau of Standards in 1927, par L. W. Austin.

No 220 : Radio Signal transmissions of Standard Frequency July to December 1929.

No 264 : Radio Signal transmission of Standard Frequency July to December 1930.

No 281 : Radio transmission of Standard Frequency January to June 1931.

b) **Du Comité National Belge :**

No 267 : Note sur le calcul des étages multiplicateurs de fréquence à triodes, par J. Marique.

No 268 : Au sujet des diagrammes dynamiques publiés par Kusunose, par J. Marique.

c) **Du Comité National Britannique :**

No 190 : The study of signal fading, par E. V. Appleton.

No 204 : The influence of the Earth's Magnetic field on Electric Transmission in the Upper Atmosphere, par S. Goldstein.

No 243 : On some measurements of the equivalent Height of the Atmospheric Ionised layer, par E. V. Appleton.

No 261 *d* : The effect of Ozone on the Temperature of the Upper Atmosphere, par E. H. Gowan.

No 262 : On some short wave equivalent Height Measurements of the Ionised Regions of the upper atmosphere, par E. V. Appleton et A. L. Green.

No 263 : Some simultaneous observations on Dawn-coming Wireless Waves, par E. V. Appleton et J. A. Ratcliffe.

d) **Du Comité National Français :**

No 233 : Nouvelles recherches sur la propagation des ondes courtes dans l'atmosphère, par R. Bureau.

No 257 : Cartes de propagation d'ondes courtes, par R. Bureau.

No 258 : 79^{e} série d'essais sur ondes courtes.

No 265 : 80^{e} série d'essais sur ondes courtes.

No 282 : Note relative aux 77^{e}, 78^{e} et 79^{e} séries d'essais sur ondes courtes.

e) **Du Comité National Japonais :**

No 193 : On the continuous record of the Atmospherics and its diurnal Oscillation, par J. Asakura et S. Fujiwhara.

No 194 : The measurements of the field intensities of some highpower long distance radio stations. — Part. I. — Bolinas et Bordeaux, par E. Yokoyama et T. Nakai.

No 195 : Idem. — Part. II. — Malabar, Palao et Rugby, par E. Yokoyama et T. Nakai.

No 196 : The effect of chemical composition on the tensivity of galena as a radiotector and the cold emission from crystals, par W. Ogawa, C. Nemoto et S. Kaneko.

No 197 : A further investigating of synthetic galena detector and a new theory of crystal rectifiers, par W. Ogawa, C. Nemoto et S. Kaneko.

No 199 : Idem que les n^{os} 194 et 195. — Part. III. Kahuku. — Pearl Harbor et Saïgon, par E. Yokoyama et T. Nakai.

No 200 : Standardization of frequency, par S. Jimbo.

No 210 : Calculations on vacuum tubes and the design of triodes, par Y. Kusunose.

No 214 : General properties of piezo-electric quartz and the value of a quartz oscillator as a frequency standards, par S. Namba et S. Matsumura.

No 221 : Idem que les n^{os} 194, 195, 199. — Part. IV. — Warsaw, Tananarive and Monte Grande, par E. Yokoyama et T. Nakai.

No 225 : Oscillation power output of a triode system and principle of its optimum design. — Part. I. -- Oscillation power output, par E. Takagishi.

No 226 : On standing electric oscillations on a line excited at a point near its current or potential loop and generation of rotary waves, par E. Takagishi et E. Iso.

No 229 : Idem que le n° 225. — Part. II. — Maximum *Pa* conditions, par E. Takagishi.

No 230 : Idem que les n^{os} 225 et 229. — Part. III. - Other optimum conditions and principle of optimum design, par E. Takagishi.

No 248 : Receiving test of French short wave stations.

No 249 : On the propagation of the short waves.

No 251 : Meteorological Influences on Long Distance, Long Wave Reception, par E. Yokoyama et T. Nakai.

No 252 : Establishment of the Radio frequency standard, par Y. Namba.

No 253 : Interim Report on Observations of atmospherics which may be caused by Meteoric Showers, par E. Yokoyama.

No 256 : Possibility of the Radio Transmission being disturbed by Meteoric Showers, par H. Nagaoka.

c) **Du Comité National Suisse :**

No 269 : Météorologie. Ionisation et champ électrique à El Golea; l'éclair visible à 800 km; mirages en automobile; condensation dans les dunes du Grand Erg. Note par M. le D^r J. Lugeon.

No 270 : Electricité atmosphérique. Le repérage radio-électrique des tempêtes de sable du Sahara, à grande distance, par M. le D^r J. Lugeon.

No 271 : Electricité atmosphérique. Mesures de l'ionisation du champ électrique et des atmosphériques au Mont-Blanc. Note par M. le D^r J. Lugeon.

No 279 : Quelques résultats de la mission météorologique suisse au Sahara en 1929.

VI. — Bibliographie.

Pendant la même période, le Secrétariat Général a publié 48 groupes de références bibliographiques dont 25 émanant du Comité National des Etats-Unis d'Amérique, 7 du Comité National Français et 16 du Comité National Japonais.

Ces références se répartissent en 17 fascicules.

Le Secrétariat Général avait cru devoir ajouter lui-même le numéro de la classification décimale aux analyses qui n'en comportaient pas. Mais il a rapidement constaté que, pour les analyses des mêmes articles, son classement ne correspondait pas à celui du Comité National des Etats-Unis. Pour éviter toute confusion, il a estimé qu'il était préférable de laisser aux personnes qui utilisent le classement décimal, le soin de numéroter elles-mêmes les analyses en question. Une note dans ce sens fut insérée dans la publication d'août 1929.

ANNEXE II.

NÉGOCIATIONS RELATIVES A LA PUBLICATION DES RÉFÉRENCES BIBLIOGRAPHIQUES DE L'U. R. S. I.

En application des résolutions prises à l'Assemblée Générale de 1928, le Secrétariat Général s'est mis en rapport avec M. le Prof^r E. V. Appleton, en vue de conclure un accord avec « Experimental Wireless » pour la publication des références bibliographiques de l'U. R. S. I. en langue anglaise.

Les offres de l'Experimental Wireless, transmises par M. le Prof^r Appleton en février 1929 étaient :

1° L'U. R. S. I. pourrait acheter les références telles qu'elles étaient publiées dans l'Experimental Wireless au prix de 1/6- l'exemplaire;

2° Pour la publication de ces références en français, dans *L'Onde Électrique*, l'éditeur de l'Experimental Wireless demandait 15/ par page, soit £ 22.10.00 par mois (références en 30 pages).

Le Secrétariat Général après en avoir référé au Général Ferrié, Président de l'U. R. S. I., écrivait à M. le Prof^r Appleton pour lui présenter quelques remarques : notamment les prix faits correspondaient à 30 pages de texte, alors qu'à cette époque les références bibliographiques de l'Experimental Wireless n'atteignaient que 11 pages par mois en moyenne.

A la suite de ces échanges de vues, le Secrétariat Général fit le 19 juillet 1929, les propositions suivantes au Général Ferrié :

1° Provisoirement le service bibliographique se ferait uniquement en langue anglaise;

2° L'U. R. S. I. ferait gratuitement le service de la bibliographie aux Comités Nationaux à raison d'un exemplaire par unité statutaire (c'est-à-dire 8 exemplaires pour les États-Unis, la France, la Grande-Bretagne, etc.);

3° Les pays qui, comme les États-Unis ont accordé à l'U. R. S. I. des subventions spéciales, recevraient un nombre d'exemplaires plus élevé;

4° Les Comités Nationaux pourraient souscrire à leurs frais, un nombre illimité d'abonnements supplémentaires à l'usage de leurs membres.

Le prix approximatif serait de 50 × 12 × 1/6 soit 5,625 francs. Cette dépense pourrait être envisagée par suite de l'intervention des firmes privées américaines.

Le 27 juillet 1929, le Général Ferrié approuvait ces suggestions.

Le Secrétariat Général transmit alors ces suggestions à M. le Prof^r^ Appleton, en portant toutefois à 60 le nombre des abonnements à souscrire au début.

Le Prof^r^ Appleton, après pourparlers avec l'éditeur de l'Experimental Wireless, fit savoir, le 15 novembre 1929, que l'Experimental Wireless était d'accord pour fournir 60 exemplaires par mois, au prix unitaire de 1/6-.

Le Secrétariat Général fit savoir, le 9 décembre, qu'il ne lui était plus possible de prendre une décision définitive, d'autres propositions ayant été faites entretemps.

En effet, à la suite de la Conférence de La Haye (septembre 1929) M. le Général Ferrié s'était mis en rapport avec le Bureau International de l'Union Télégraphique de Berne, qui était tout disposé à publier gratuitement, dans le *Journal Télégraphique de Berne*, les références bibliographiques de l'U. R. S. I.

Le 4 novembre 1929, le Secrétariat Général adressait à tous les Présidents des Comités Nationaux, un programme relatif à la publication des références bibliographiques dans le *Journal Télégraphique*.

Chaque Comité National enverrait tous les mois au Secrétariat Général de l'U. R. S. I. une courte analyse (10 à 15 lignes au maximum) de chaque travail publié dans son pays concernant la radiotélégraphie scientifique. La personne qualifiée, qui rédigerait ces analyses, recevrait une indemnité, pour autant que le budget de l'U. R. S. I. le permettrait. Le Secrétariat Général de l'U. R. S. I. prendrait toutes mesures utiles pour avoir aussi des analyses des travaux publiés dans des pays n'appartenant pas encore à l'U. R. S. I.

L'ensemble de ces analyses, convenablement classé, serait envoyé au Bureau de Berne pour être publié dans la Revue appartenant à cet organisme. Des tirages à part de cette bibliographie seraient ensuite envoyés à chaque Comité National dans des conditions à fixer d'accord entre celui-ci et le Secrétariat Général.

Des articles, donnant l'état d'avancement de chacune des études entreprises par l'U. R. S. I. seraient, en outre, demandés chaque année aux physiciens qualifiés et publiés dans la REVUE DE BERNE. Des tirages à part seraient encore demandés et distribués.

Le Comité Français répondit le 4 mars 1930 que la seule solution qui lui paraissait possible étant donné le budget précaire de l'U. R. S. I. était de publier les références dans le *Journal Télégraphique de Berne*. Le Comité des États-Unis d'Amérique ne put donner de réponse à ce moment son Comité Exécutif devant se réunir en avril.

Le 1^er^ avril, le Secrétariat Général reprenait ses propositions, et proposait de publier immédiatement les références dans le *Journal Télégraphique;* il demandait aux Comités Nationaux de lui envoyer les analyses des articles scientifiques intéressant l'U. R. S. I. dans la forme rappelée ci-dessus.

Les Comités Suisse et Néo-Zélandais répondirent qu'ils s'occuperaient de la chose. Le Comité des États-Unis fit remarquer qu'un service bibliographique suffisant existait actuellement (références publiées par le *Radio Research Board*, et par le Bureau of Standards) et que le Secrétariat Général devrait se borner à fournir des références complémentaires qui lui seraient communiquées par les Comités Nationaux.

En conclusion, les propositions du Secrétariat Général ne reçurent qu'une approbation partielle; il fut donc contraint, en l'absence de directives, de continuer à publier lui-même les analyses américaines, françaises et japonaises dans la forme où elles lui parvenaient.

Travaux des Commissions.

Proceedings of the Commissions.

NOTICE HISTORIQUE.

La Commission des *Méthodes de Mesures et d'Étalonnages*, la Commission de *Propagation des Ondes*, la Commission des *Perturbations Atmosphériques* et la Commission de *Liaison avec les Opérateurs, les Praticiens, les Amateurs et les Sciences Connexes* furent instituées par décision de l'Assemblée Générale de l'U. R. S. I., tenue à Bruxelles en juillet 1922.

La Commission de *Radiophysique* fut instituée sous le nom de Commission des *Oscillations*, par l'Assemblée Générale tenue à Washington en octobre 1927; cette dénomination fut changée lors de l'Assemblée Générale tenue à Bruxelles en septembre 1928.

L'activité des Commissions depuis l'Assemblée Générale de 1922 jusqu'à l'Assemblée Générale de 1928 est résumée dans les fascicules 3 à 6 du volume I et dans le fascicule 3 du volume II de l'U. R. S. I.

Les travaux exécutés par les différents Comités Nationaux et Commissions de l'U. R. S. I. depuis l'Assemblée Générale de 1928 ont été résumés et discutés au cours de l'Assemblée Générale tenue à Copenhague en mai-juin 1931, et des programmes de travaux ont été élaborés pour l'avenir.

HISTORICAL NOTICES.

The Commission of *Measurements and Standardization*, the Commission of *Radio Wave Propagation*, the Commission of *Atmospherics* and the Commission of *Cooperation with Operators, Practitioners, Amateurs and Connected Sciences* have been constituted by the decision of the General Assembly held in Brussels in July 1922.

The Commission of *Radiophysics* has been instituted under the name of Commission of *Oscillations*, by the General Assembly held in Washington in October 1927; this denomination was changed during the General Assembly held in Brussels in September 1928.

The activity of the Commissions from the General Assembly of 1922 until the General Assembly of 1928 is summarized in fascicules 3 to 6 of volume I and fascicule 3 of volume II of the U. R. S. I.

The works made by the various National Committees and Commissions of the U. R. S. I. since the General Assembly of 1928 have been summarized and discussed during the General Assembly held in Copenhague in May-June 1931, en programs of works for the future have been elaborated.

COMMISSION I. — MÉTHODES DE MESURES ET ÉTALONNAGES.

COMMISSION I. — MEASUREMENTS AND STANDARDIZATION.

INTRODUCTION

La Commission des Méthodes de Mesures et Étalonnages est composée de la façon suivante :

The Commission on Measurements and Standardization is composed in the following way :

Président :	M. le Dr DYE, D. Sc., F. R. C., du National Physical Laboratory.
Belgique :	MM. M. R. CORTEIL, Directeur du Service des Radiocommunications de l'Administration des Télégraphes; M. J. MARIQUE, Ingénieur du Service de l'Aéronautique et M. R. MOENS, Chargé de Cours à l'Université de Gand.
États-Unis :	M. le Dr J. H. DELLINGER, Chief of Radio Section, Bureau of Standards.
France :	M. le Profr ABRAHAM, Professeur à la Sorbonne et M. le Profr R. JOUAUST, du Laboratoire Central d'Électricité.
Grande-Bretagne :	M. le Dr D. W. DYE, M. le Profr E. V. APPLETON, Wheatstone Laboratory, King's College; M. O. F. BROWN, Department of Scientific Research; le Capt. P. P. ECKERSLEY, British Broadcasting Corporation, Sir Joseph PETAVEL et M. le Dr F. E. SMITH.
Italie :	M. l'Ingénieur Tullio GORIO, Inspecteur Supérieur Technique des Postes et Télégraphes; M. le Tenante-Colonel F. AMOROSO et M. le Commandant MATTEINI.
Japon :	M. le Colonel Z. ISHII, Military Scientific Laboratory; M. le Profr T. KUJIRAI, Faculty of Engineering, Tokyo Imperial University; M. le Dr T. MINOHARA, Ordnance Rear-Admiral, Naval Experimental and Research Establishment et M. le Dr K. TAKATSU, Electrotechnical Laboratory.
Norvège :	M. le Profr H. PEDERSEN, Ingénieur en Chef à l'Administration des Télégraphes et M. le Profr VEGARD, Professeur à l'Université d'Oslo.
Nouvelle-Zélande :	M. le Dr M. A. F. BARNETT, Department of Scientific and Industrial Research.
Pays-Bas :	M. A. DUBOIS; le Dr Ir. KOOMANS et M. le Dr B. VAN DER POL, du Natuurkundig Laboratorium der N. V. Philip's Gloeilampenfabrieken.
Portugal :	M. le Capitaine de Vaisseau A. RODRIGUES, Professeur d'Électrotechnique à l'École Navale.
Suisse :	M. le Dr J. LUGEON.

COMPTE RENDU DE LA SÉANCE DU VENDREDI 29 MAI.

ACCOUNT OF MEETING OF FRIDAY, MAI 29.

La séance est ouverte à 16 heures sous la présidence du D^r^ D. W. Dye, Président de la Commission I, assisté du Prof^r^ Jouaust comme Vice-Président et du Prof^r^ Latour comme interprète.

The Chairman reads a report (¹) setting forth the present general position of radio-frequency standards and measurements with special reference te frequency and its association with time.

Le Prof^r^ Jouaust attire l'attention sur l'importance des remarques de M. le Président, particulièrement en ce qui concerne l'emploi des horloges piézo-électriques qui peuvent remplacer les horloges à pendule. La France a déjà envisagé leur utilité, non pas en les substituant, mais en les employant en même temps que les horloges à pendule.

Le R. P. Lejay a publié à ce sujet un travail important sur la détermination de la constante de gravitation pour des temps courts. Ce qui pourrait donner des renseignements sur les marées terrestres dues à la lune.

D^r^ Dellinger remarks that very carefully constructed quartz oscillators could, under suitable conditions, be considered more accurate than the pendulum-clock. At the Bureau of Standards an equipment consisting of four piezo-oscillators gives a constancy of 2 parts in 10 million. The arrangement permitted the continuous recording of beats between one oscillator and each of the other three. On the long running, it is more accurate than the time signals. The accuracy of such oscillators enables them to be used as Prof^r^ Jouaust suggests for gravity observations.

The Chairman then gives a brief account of the International Comparison Measurements since 1928 as drawn up in the Report of Great Britain to Commission I (²).

He then refers to a statement made to him by D^r^ Dellinger that at the Bureau of Standards it was envisaged to have a highly constant transmission at 5 000 kc/s. maintained absolutely continuously day and night. The Chairman refers to the great possibilities inherent in such a transmission modulated in various ways at the same time.

Le Prof^r^ Jouaust s'excuse de ne pas avoir présenté un rapport et fait remarquer qu'il a été absorbé par le C. C. I. R.

Il signale qu'en France on utilise comme point de départ pour les mesures de fréquences un diapason de 1 000 périodes, maintenu continuellement en oscillation et entraînant un mécanisme d'horlogerie dont on peut comparer les indications à celles d'un pendule de l'Observatoire.

Au début, on utilisait un diapason de 1 024 p/s, appareil dont la fréquence correspond à une note musicale existant normalement dans le commerce.

C'est en modulant avec ce diapason le poste radio-téléphonique de la Tour Eiffel qu'ont été exécutées en collaboration avec le National Physical Laboratory, la Physikalisch Tecnische Reischsantalt et le Laboratoire de l'Académie Navale de Livourne, les mesures comparatives demandées par le C. C. I. R. Des accords de quelques millionièmes furent ainsi obtenus.

Des mesures simultanées de la fréquence de l'onde porteuse furent aussi essayées. Les variations rapides de cette fréquence rendaient ces mesures difficiles.

Le mode opératoire suivant permet de tourner cette difficulté. Au cours de l'émission, chaque

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(¹) Annexe I, p. 16.

(²) Annexe II, p. 18.

laboratoire intéressé dans la mesure, exécutait des mesures de fréquence aussi nombreuses que possible et notait l'heure de ces mesures. Pour chaque laboratoire, on traçait la courbe donnant en fonction du temps les fréquences mesurées. On constata que ces courbes se superposaient à environ 10^{-5} près quoique les variations fussent de l'ordre de 10^{-4}. On avait donc le droit de conclure que dans ce cas les mesures des divers laboratoires concordaient au cent-millième près.

D^r Dellinger comments on the satisfactory agreement to 1 in 10^6 obtained. He states that recent measurements show the same agreement between the U. S. A. and Italy. The Italians were successful in receiving the Bureau of Standards' 5 000 kc/s. transmissions and have obtained agreement to 1 in 10^6 with them.

He refers to the program of these transmissions every Tuesday afternoon and evening for two hours at a power of 1 K. W., measurements on this transmission made at three laboratories in the U. S. A. equiped with primary frequency standards have given agreement to 2 parts in 10^7.

Further plans are to increase the power to 20 K. W. so as to be ready in 1932, time working every Tuesday for 2 hours at 5 000 kc/s. and at 15 000 kc/s. It is intended to operate this for one year in order to see wether a day and night service is practicable and eventually to operate continuously every day.

Le Prof^r Jouaust estime que l'idée du D^r Dellinger sera très utile si une transmission de vingt-quatre heures est possible. Il a écouté mais n'a pas réussi à entendre la transmission de 5 000 kc/s. quoiqu'il ait passé plusieurs nuits à l'essayer. Des signaux de cette fréquence sont généralement bien reçus en France vers deux heures du matin, mais on n'est pas sûr de les recevoir à un moment quelconque de la journée. Avec une émission d'une durée de vingt-quatre heures, il y aura certainement des moments pour lesquels la réception sera assurée.

D^r Van der Pol refers to the fading which occurs on short-waves at long distances and indicates that phase variations make difficulties in defining the frequency.

D^r Dellinger agrees as to the effects of the properties of the medium and appreciates that they must be considered when accuracies of a few parts in 10^7 are involved. This order of effect has been observed. The question is also of importance when considering the choice between high frequency measurements and measurements on a low frequency modulation.

Le Prof^r Jouaust fait remarquer qu'il a fait des essais de l'effet Döppler sur les signaux horaires de Washington où un oscillateur au quartz était utilisé, mais qu'il n'a pas entendu de variations dans la fréquence de battement.

D^r Van der Pol remarks that from theoretical considerations the variation of frequency would be of the same order as the frequency of fading.

Le Prof^r Mesny dit qu'il se souvient des observations de Rukop, en 1926, sur la transmission allemande des images entre Rome et Berlin. La transmission d'une ligne droite montrait des déviations correspondantes à un effet Döppler de 1 000 cycles sur une fréquence de 8 mégacycles/sec.

Il estime cependant, que pour des comparaisons, les effets peuvent être négligés car ils sont momentanés et une observation de quelque durée permet de les éliminer.

The Chairman remarks that the matter could be considered from two points of view :

1. That of mean frequency, and 2° that of an instantaneous frequency (though this term presents difficulties in definition).

For frequency intercomparison purposes a mean frequency was always measured and since the number of waves between transmitting and receiving stations was always comparatively few, there could never arise much uncertainly where a period of several seconds or a few minutes was involved.

The instantaneous observations might, however, be of value scientifically in connection with the propagation of waves.

D^r Van der Pol agrees with the Chairman's remarks. He refers also to the results of comparison measurements between quartz oscillator clocks and pendulum clocks made at the Loomie Laboratories in Tuxedo Park. These results when carefully analysed indicated a definite luner component of gravity.

The Chairman remarks that no proposals had been received beforehand.

Le Général Ferrié fait remarquer que le Président pourrait faire ces propositions.

The Chairman then submits that the specially steady transmissions at 5 000 kc/s. from the Bureau of Standards should be exploided to their fullest extent. He remarks that he has failed himself to receive these signals but anticipated success in the future.

Le Général Ferrié annonce qu'en France, on a l'intention d'effectuer des émissions d'ondes courtes pour l'étude de la couche Kennelly-Heaviside. Ces émissions pourraient servir en même temps pour d'autres mesures. Le Comité National Français enverra le programme de ces émissions à tous les Comités Nationaux.

The Chairman then refers to the value of vacuum type of quartz resonator as perfected by Dr Giebe. These resonators have been found very constant and very convenient in recent-intercomparison measurements and the Chairman feels that they could very usefully employ these resonators.

Le Dr Lugeon fait remarquer l'importance pour la Commission II des émissions faites pendant vingt-quatre heures. Ces émissions permettront l'enregistrement des effets du rayonnement solaire sur la couche ionisée.

Des émissions simultanées sur 5 000 et 6 000 kc/s. permettraient de reproduire graphiquement, en trois dimensions, les effets du rayonnement solaire, le long du trajet de l'onde.

Dr Dellinger thanks the Chairman for calling attention to the 5 000 kc/s. transmissions from the Bureau of Standards and states that he would welcome any suggestions whereby they may serve various purposes.

He thinks that the simultaneous transmissions of two neighbouring frequencies would be difficult, specially at high power where the running expenses were necessarily heavy. He considers it desirable to concentrate on one frequency.

Le Profr Jouaust fait remarquer que la Commission I n'a pas pour objet l'étude de la propagation des ondes mais cependant le champ produit par celles-ci doit toujours être mesuré. Si on emploie des appareils qui ne sont pas identiques, mesure-t-on la même quantité?

Il estime que la Commission I devrait examiner cette question. Elle pourrait rédiger un questionnaire et un syllabus des méthodes standardisées, de façon que tous effectuent les mesures dans les mêmes conditions.

Il propose que le Président se renseigne pour obtenir la description des appareils employés pour les mesures de l'intensité du champ et que lors d'une prochaine assemblée ces appareils soient standardisés pour avoir la certitude que tous mesurent la même quantité.

The Chairman asks for suggestions or comments on this question.

None are made. He then suggests that he could undertake to collect information.

Dr Smith-Rose mentions that apparatus for field intensity measurements base their results upon two quantities, one is current and the other is effective resistance of an aerial or other receiving system. He suggests that it is desirable to have standards of current and resistance but thinks that these are not matters for international action. On the other hand the apparatus used in different countries is very different and the quantities measured might well be different so that the agreement might be difficult to attain. He thinks that the matter should receive attention.

Le Profr Mesny pense qu'il est très important de pouvoir apprécier d'une façon précise les différentes méthodes utilisées pour les mesures de champ et que l'étude et la comparaison de ces méthodes s'imposent aujourd'hui qu'elles sont bien définies. Il rappelle qu'il fut décidé à Washington de faire en un même lieu des mesures comparatives avec des appareils différents ce qui pourrait amener le transfert de cette question de la Commission II à la Commission I.

The Chairman then refers to matters concerning the relations between the U. R. S. I. and the C. C. I. R. in regard to questions of frequency standards and measurements since there is considerable overlapping.

Dr *Rayner* reads a proposal to form a small sub-committee to deal with standards.

This is not made clear to General Ferrié whereat the *Chairman* explains that there is no intention to form a standing Committee of the C. C. I. R. since this is outside the scope of both C. C. I. R. and U. R. S. I. but a small permanent committee could be formed as an independant committee or in association with the U. R. S. I.

Dr *Dellinger* says that he assumes that it was not intended to take action on the matter at present.

The Chairman replies that the idea was only a suggestion for consideration.

La séance est levée à 18 heures.

ANNEXES.

I. *Chairman's Report to Commission I.*

II. *British National Committee. — Report for Commission I on the present status in Great-Britain of Radio Frequency Standards Measurements.*

ANNEXE I.

CHAIRMAN'S REPORT TO COMMISSION I OF THE U. R. S. I.

Frequency.

The measurement of periodicity is a pure measurement in time and its inverse is frequency with which we are largely concerned in our Commission.

Frequency can be produced, measured, multiplied and demultiplied with a precision which has placed it in the first order amongst measurements of all kinds.

We are approaching the condition of a structure of measurement of greater rigidity than the foundations of time upon which it is at present based. We are therefore compelled to look to these foundations in order to stabilise them more and more to keep pace with the ever-increasing accuracy available in the measurements referred to.

The advances made in steadiness of frequency production all over the world during the last few years have been extremely rapid we have, in about three years, increased the accuracy of measurement by at least ten fold.

Great advances have been made in the construction of primary frequency standards in various laboratories. Mention must first be made, in this connection, of the remarkable piezo-electric quartz oscillators developed at the Bell Telephone laboratories in New-York, and adopted by the Bureau of Standards as their primary frequency standard. Much investigatory work has also been carried out on tuning forks as primary standards in Great-Britain, Japan, France and else where.

A feature which has resulted in a great improvement in performance in these standards and on which is growing in practice is the principle of keeping the primary frequency standard in a state of continuous oscillation day and night.

This is a matter, which must receive serious attention in all national laboratories in which frequency standards are installed. No one would think of starting and stopping a pendulum clock every time it was required to mark time. In a similar way we must not start and stop our frequency standards each time they are used. It is now realised that continuous operation is essential to the highest performance and there are several laboratories in which primary frequency standards are maintained in completely continuous operation. The extension of such a condition in other laboratories would appear to be of first importance.

Once this principle is established, it becomes a very simple matter to integrate the vibrations continuously and thus turn the oscillator into a clock. There is very little information regarding the day to day stability of vibration clocks by direct comparison with time signals.

Further close collaboration between laboratories possessing highly accurate vibration clocks and astronomical observatories is needed and in those laboratories possessing both pendulum clocks and vibration clocks, comparison observations at short intervals of time — not greater than one hour — will afford most valuable information.

This work is in progress in at least three laboratories, but it is too soon yet to draw any generalised conclusions.

It would seem that time as actually given us by the observatories, is really an average result of observations made on stars and on clocks. Neither is reliable without the other. The fact imerges that one day is not a long enough period to enable astronomical time to be observed to the highest accuracy now desirable and we have to depend more and more upon vibrational time integraters (clocks) of whatever kind to smooth out irregularities in star observations. The clocks have virtually to integrate time over several days, at present this duty is taken by pendulum clocks which it may be conceded are probably the most satisfactory and convenient integrater for the purpose. But a pendulum has too long a period to give the highest accuracy of time subdivision as required by wireless frequency standards owing to difficulties associated with fine subdivision of one oscillation.

The present position may be summed up as follows :

1° Guardian of time itself — the rotation of the earth;

2° Guardians of the day — the rotation of the earth and pendulum clocks;

3° Guardians of the second — pendulum clocks and vibration clocks;

4° Guardians of telephonic and wireless frequencies — mechanical oscillatory systems of various kinds.

This chain of links between time and wireless frequency standards cannot easily be shortened at present, but it may be anticipated that the pendulum clock may ultimately disappear as far as wireless frequency standards are concerned.

The primary frequency standards in all national laboratories are single-valued standards and the means used to obtain multiple, submultiple and nonmultiple frequencies from the standard differ in each laboratory, but all, I think, without exception utilise harmonic principles as far as it is possible to do so whether for the measurement or production of harmonic or inharmonic frequencies of accurately known value. Interpolation or difference frequency measurements must be used when nonintegral frequencies are involved, but these are relieved of as much responsibility as it is possible to do in nearly all cases.

The position is such that the measurement of any unknown frequency can be made in several national laboratories to an accuracy superior to the constancy of the source of the frequency, and generally speaking short-period or momentary frequencies can be measured to a very few parts in a million.

Wavemeters.

A very excellent account of the position in respect of wavemeters usually forming secondary standards has been given in a document drawn up by the Italian Government and presented to the C. C. I. R. It is obviously impossible to go into the matter raised there in detail, but I will venture the opinion that the actual performance of wavemeters as at present constructed is not so good as it might be in the light of the knowledge now available on the subject. It is suggested that designs of these valuable instruments could now be drawn up and such instruments be constructed to meet any requirements demanded of them.

In all other measurements, except frequency, a large reduction in the accuracy demanded occurs, with the exception perhaps of certain phase angle or loss measurements on condensers.

The foundations of measurement of inductance and capacity are well enough laid and, in all countries possessing primary electrical standards, are dependent either upon standard inductances calculable from their dimensions or for capacity only the basis used is resistance and time.

The measurement of current and voltage are not of supreme importance in wireless research and have therefore not received nearly as much attention as frequency. There would seem, however, to be need for a certain amount of cooperation internationally in connection with the measurement of current, since currents are produced in aerials in one country and the resulting small currents or voltages in aerials or loops in other countries are measured in relation to one another.

The difficulties associated with international comparisons of methods of field intensity measurement, for example, are very great since different countries measure different quantities by the various types of apparatus which they use.

In the field of very high frequency current measurement considerable work has been done towards placing such measurements upon a sound basis. These are referred to in the report of the National Committee of Great Britain to Commission I in which several methods are described.

There remains a vast field of measurement falling under the general reading of « general measurements and properties of circuits ». It is utterly impossible to do justice to this field now, and the matter is not one which really requires any international action. I have tried to summarise the present position in this field in Great-Britain in the above-referred to report of Commission I, a fairly complete bibliography is also appended to that report.

D.' Dye.

ANNEXE II.

British National Committee

REPORT FOR COMMISSION I ON THE PRESENT STATUS IN GREAT-BRITAIN OF RADIO FREQUENCY STANDARDS MEASUREMENTS.

The Report covers the period since the beginning of 1928 down to the time of writing. As in previous reports, the subject matter is grouped under the headings :

1. Frequency.
2. Current and Voltage.
3. Inductance and Capacity.
4. General measurements and properties of circuits.

1. FREQUENCY.

(*a*) Primary Frequency Standards.

Advances have been made in radio frequency standardisation in several directions.

In the first place the measurement of time has received considerable attention and the correlation of time with the standards of frequency has been made much more precise during the past three years.

The present position is such that in this country pendulum clocks still hold the field as accurate time keepers for daily and longer periods. The use of time signals transmitted in close cooperation with observatories, constitutes the means of determining the daily rates of standard clocks. It has been found at the National Physical Laboratory that time signals from Greenwich Observatory via Rugby are in remarkably good agreement with those from the Paris Observatory via the Eiffel Tower. The signals from Nauen appear to be less regular and to give a consistent small time difference from other two Observatories. Time signals from Washington have been received at the N. P. L. and at Greenwich Observatory but not with good regularity. As a regular practice, therefore, at the N. P. L., the rates of the standard clocks are determined from the Greenwich and Paris time signals only.

It is hoped in the future that more observatories can be included in the determinations of mean time, in order to obtain more exact information regarding the rates of clocks and the variation of rates during the 24 hour periods.

It may be stated that the precision with which the rates of clocks of the Shortt type such as are used at the N. P. L. and at Greenwich retain their diurnal constancy, is of the order ± 0.03 seconds per day corresponding to an uncertainty of 4 parts in 10^7.

In England the link between the clock as a time marker and frequency is made almost exclusively by means of tuning forks.

The increasing demands for more and more accuracy in the standards and in the measurements of frequency has shown the necessity of maintaining the standards in a condition of continuous operation.

At the N. P. L. and at the Post Office, tuning forks are maintained in vibration continuously and here and in other laboratories the frequency can be integrated up by means of phonic wheels so as to enable time to be recorded by tuning forks, thus converting them to clocks.

At the N. P. L. the equipment consists of two tuning forks mounted in a constant temperature, constant pressure enclosure, and operated under conditions of batteries, etc., such that a constancy from hour to hour and from day to day is maintained to less than one part in a million. One of these forks drives a phonic wheel and chronograph drum, designed so that impulses once each hour can be recorded upon the drum, the impulses being obtained from a Shortt clock. In this way the hourly rate differences between pendulum clock and tuning fork clock are continuously recorded. The chronograph drum, of 5 cms. diameter, revolves once per second, and the impulse is traversed one mm. per hour along the axis of the drum. The surface of the drum thus travels about half a kilometre per hour so that the line of marks on its surface will make an angle of 45° with the drum axis for a rate difference of only two parts in a million. The slope of the line can be read by inspection at any time from a scale, and thus enables the rate difference to be determined to one or two parts in ten million.

The second tuning fork referred to above, has a frequency about one part in a million different from the first one and hourly rate differences between the two forks are also recorded upon the drum. A check is thus kept upon the regularity of the three time markers.

The mean rates of the tuning forks for 24 hour periods can, of course, be obtained directly from the astronomical time signals without the auxiliary of any pendulum clock in the Laboratory. This is done also at the Post Office using the Rugby time signals. It should be realised, however, that the mean rate of observatory pendulum clocks, over several days' time interval, constitutes the real basis of time signals since transits cannot be observed every day, neither are they observable to the accuracy at present obtainable in frequency comparisons. This may be expressed by the statement that the real unit of time is not one revolution of the earth round its axis but several revolutions. The time subdividers must, therefore operate with regularity for days at a time and pendulum clocks appear to be superior to all other time integrators for such periods.

The present state in Great-Britain is such that an accuracy and regularity of frequency is being maintained to about one part in a million continuously.

Considerable work has been done at the N. P. L. and in other laboratories towards perfecting tuning forks both as frequency standards and for frequency control purposes.

In particular at the N. P. L. the investigations during the last three years have included :

(*a*) Variation of damping coefficient with various modes of maintaining the fork and with various intensities of polarising magnetisation when used.

(*b*) Variation of frequency with variation of amplitude, temperature, pressure, battery voltages and valve constants, type of subsidiary valve circuits.

(*c*) Effects of method of mounting and of varying known amounts of unbalance in the prongs. From the latter investigations a very sensitive and accurate method of balancing has been evolved, whereby an almost perfect independance of the frequency with mounting conditions results.

(*d*) Ageing characteristics with respect to time and to repeated temperature cycling have also been investigated.

These investigations have been supplemented by many others made at the Marconi Co. 's laboratories and by the B. B. C., Post Office, etc., and considerable work is still in progress in order to improve still further the constancy and reliability of this particulary convenient form of frequency standard.

The investigations of the Marconi Co. indicate that well-annealed mild steel has a better stability than the special alloy steels of small temperature coefficient. Such mild steel forks are used by them and by the B. B. C. in spite of their large temperature coefficient, the measurement of frequency necessitating of course, accurate temperature control.

Tuning forks, by their considerable thermal mass, can, however, be kept constant in temperature to 0.01° without difficulty. They are so kept in the cases quoted above, so that even in commercial transmissions, and in broadcasting, frequency constancy to a few parts in a million is maintained in stations equipped with tuning fork control.

More information is needed regarding the ageing of forks, the effects of heat treatment and temperature cycling, composition of the steel. A comparison of various methods of driving including electric capacity drive in a vacuum as an alternative to the almost universal electromagnetic maintenance at present used, would give information of great value.

Other frequency standards which may be classed with tuning forks, are steel bar vibrators maintained in longitudinal vibration. Much work has been done at the N. P. L. on such a frequency standard in the form of a bar of elinvar 1 metre long, of frequency about 2 500 cycles per second, driven by electric capacity coupling to small electrodes, one at each end. For low frequencies, such a form of standard appears to be superior to a tuning fork, but, of course, is somewhat bulky and requires special heat control to maintain its lenght at constant temperature. Such a standard has been permanently set up at the N. P. L. but actual results on its behaviour are not at present available.

(*a*) **Magnetostriction Oscillators.**

Next in order of frequency come magnetostriction oscillators, and some work has been done by Vincent and at the Admiralty Research Laboratory on such oscillators. Some preliminary work carried out at the N. P. L. indicated that such oscillators were never likely to equal tuning forks in constancy of frequency owing to greater damping, and to the large effects on frequency of the essential magnetisation. Two important papers on the subject, one by F. D. Smith on a ring form of oscillator vibrating in fundamental radial mode, and another by S. Butterworth on the equivalent electric network of a magnetostriction oscillator, must be mentioned. In particular, the latter paper sheds much light upon the conditions prevailing and upon the large effects of eddy currents upon the whole behaviour of the vibrations and their reactions upon the maintaining circuit.

(*b*) **Quartz Resonators and Oscillators.**

A considerable amount of work has been done in various Government laboratories upon piezoelectric oscillators, but only a meagre amount of information is available on the subject from these sources.

A novel form of oscillator of the bar type, has been developed by Lucas at the Air Force Establishment. The bar is mounted in an evacuated glass bulb and vibrates longitudinally in various Government laboratories upon piezo-bar itself is at its centre by means of cork. The electrodes leave an appreciable air gap which is maintained constant. The frequency coefficient is about —3 x 10^{-6} in accordance with the elastic properties of quartz in any direction perpendicular to the optic axis. Specially insulated valves are desirable for use with such oscillators, but otherwise the circuit conditions are normal and the frequency variations according to theory.

Convenient ranges of frequency are from 50 to 100 kilocycles per second, so that the complete mounted bar in its bulb is of compact size and easily be temperature controlled, when desired.

On the theoretical side, valuable contributions have been made by Vigoureux, who has developed the equations connecting the mechanical vibrations in quartz bars with the piezo-electric and the dimensional constants. The agreement between the theory and experiments on such bars has shown that they behave in a simple manner with nearly pure longitudinal motion for cases where the lenght dimension is large compared with the cross-sectional dimensions. It may be stated that for such bars, our knowledge is fairly complete, but that some work on the effects of the small sheer component upon the temperature coefficient of the vibrations is needed and wil probably be carried out.

The piezo electric oscillator has also been thoroughly investigated by Vigoureux, at the N. P. L., and the effects of variation of all the external circuit conditions worked out and tested experimentally. Using the equivalent network of the quartz-electrode system, and developing the equations for maintenance of oscillations when the system is associated with a valve and suitable circuits, of the simple tuned anode circuit type, it has been proved that the behaviour conforms closely to that predicted by theory. The matters investigated included the grid-filament and grid-anode modes of connection. It was found, experimentally and theoretically, that when the capacity in the anode circuit was *greater* than a certain value, oscillations were impossible at the frequency concerned, whilst for the grid-anode connection, oscillations were impossible for a capacity *less* than the same critical value. The frequencies were considerably different for the two critical conditions, — about one part in ten thousand, — but approached very nearly to each other as the critical conditions are receded from on each side.

These effects and the effects of varying grid-anode and grid-filament admittances have been studied in detail and have shown good agreement between experiment and theory.

Given therefore the equivalent network of the quartz-electrode element of an oscillating system, it may be taken that the behaviour under any external set of conditions is predicable.

The work done in connection with the analysis of a quartz crystal electrode element into its equivalent network, has shown that no agreement with theory based on a simple compressional or shear vibration, is obtained. The conclusion reached is that the vibrations are complex and this has been borne out by the work of Dye on the modes of vibration of piezo-electric quartz plates as revealed by an interferometer arrangement, whereby the nature of the vibrations is seen by eye, by examination of interference fringes obtained between the upper polished surface of the plate and a reference surface supported just above and very close to it.

By this means, a large variety of plates has been examined at the N. P. L. Most of the plates have been cut with plane perpendicular to an electric axis, but a few have also been cut with plane containing an electric and the optic axis. The plates were found to *all* show several modes of vibration near that corresponding to the fundamental compressional mode in thickness direction. When these various modes are examined in the interferometer, it is immediately seen that they are complicated. The important conclusions drawn from these experiments are that when a plate vibrates in either fundamental compressional mode, or in fundamental shear mode, according to type of cut, at frequencies corresponding to thickness direction of vibration, then, associated with this type of vibration (which must necessarily occur), there are other overtone compressional, flexural, torsional or other kinds, in directions parallel with the plane of the plate. These components of the resultant vibrations absorb energy and involve additional stresses in the material which are undesirable and result in a great reduction of the effective piezo-electric reaction of the plate upon its electrodes, and risk of fracture and temperature rise. The temperature coefficient of the resultant vibration is greatly dependant upon the relative values of the components of the motion, since quartz has very different temperature coefficients of moduli in varying directions.

Work is in progress upon the analysis of the resultant motion into its components using rectangular plates and operating upon the dimension ratio of thickness to each of the other two dimensions. This observation of resonant crevasses and their relative positions and intensities as functions of temperature, together with photographs of the mode of vibration as given by interferograms constitutes one of the important investigations to be made upon quartz plates not only from the point of view of their use as frequency standards, but also to obtain fundamental information upon the relationships of the various elastic moduli to one another and to the boundary conditions of the plate. The general mathematical solution of such a problem is well nigh insuperable but attempts at some simplified cases are being undertaken.

On the pratical side, the use of piezo-electric oscillations steadily becomes more wide-spread, but in general lags behind the possibilities and behind development in other coutries. As a general statement, it may be said that entirely satisfactory plates can be cut and adjusted to any desired frequency up to about 5 $\times 10^6$ cycles per second. The boundary conditions at the plate edges can always be adjusted so that one mode of vibration predominates and is the only one at which oscillation occurs. The adjustments of temperature coefficient by adjustment of boundary conditions so as to obtain a zero or very small temperature coefficient, are not yet under control for plates vibrating compressionally at any frequency, nor for plates vibrating in shear for frequencies greater than 1 $\times$ 10^6 cycles per second.

A new type of oscillator in the form of an annulus of quartz cut with plane of the ring perpendicular to the optic axis and mounted in an electrode system connected so as to maintain the fundamental longitudinal mode, has been experimented upon at the N. P. L. and shows great promise as a standard for the highest possible precision. The rings vibrate in such fashion that the mean diameter expands and contracts, every part of the ring having a radial vibration. The stress and strain are uniform all round the ring and are of pure compressional kind. The temperature coefficient is not yet known but will certainly be very small. The frequencies for which such rings can be made conveniently, range from 20 000 to 50 000 cycles per second.

Summarising the present position in relation to frequency production and standardization, it may be stated that for frequencies up to 3 000 cycles per second, tuning forks are used; up to 50 000 cycles per second harmonics of tuning forks and, to a much less extent, magnetostriction oscillators, are used; from 50 000 up to 1 000 000 cycles per second quartz oscillators and multiplied frequency from tuning forks are used, and to a small extent purely electrical valve systems. The extension of the region to 5 000 000 cycles per second, is governed by the use of quartz oscillators and special electrical circuits. Above 5 000 000 cycles per second, harmonic control from crystal oscillators is chiefly used, but considerable attention has been given to purely electrical oscilatory systems, in particular by the Marconi Co.

The electrical oscillatory system as a standard of frequency is beginning to receive attention, and its possibilities are being explored. Work by the Marconi Co. on master oscillators in the frequency region 5 to 30 mega-cycles per second shows considerable possibilities meriting further investigations. By suitable choice of materials and design in the essential oscillatory circuit temperature coefficients as small as 1 in 10^6 have been obtained. The conditions to be satisfied in the valve circuits have also been explored mathematically and experimentally by E. Mallett and F. Colebrook and others. The former has shown how the use of a series anode reactance can be used to compensate for the changes in frequency which would otherwise occur, due to change in the valve characteristics.

Since in all valve oscillatory systems the amplitude built up must be defined by a departure from linearity in the valve or circuit characteristics, harmonics must inevitably be introduced and a variation in fundamental frequency will also result. The conditions associated with this non-linearity have not been fully developed owing to mathematical complexity but simplified cases have been worked out by Colebrook and suggestions for further theoretical and experimental work are seen to be highly desirable.

In closing this section on frequency standards from the point of view of maintained frequency, the writer feels justified in quoting a short abstract of a note by A. S. Eve in « Nature » on the « Growing Importance of Frequency ». « A scientific status for frequency is urged comparable to that for energy, mass and heat. The conservation of energy has its counterpart in the conservation of frequency. In place of the linkages in nature such as $e = mc^2 = hf = Jq$, we can, by adopting « Superunits» write down $E = M = F = Q$ wherein energy, mass, frequency and heat all appear expressed with the same number. Also the Einstein-Bohr equation $h\nu = W_1 - W_2$ can be written $\nu = f_1 - f_2$. The linkage between energy and time suggests a close relationship between energy and frequency ».

Wavemeters.

Wavemeters by which frequency is read or deduced from a scale reading, may rightly be included under standards, if of suitable quality and advances in design and construction, during the last three years have shown that resonating and oscillating wavemeters have notably advanced in accuracy and permanence.

Some of the aspects of oscillating wavemeters have been touched upon above in connection with purely electrical frequency standards. The principles laid down have been carried into practice in oscillating wavemeters constructed at the N. P. L. to cover a range from 10 to 20 000 metres. D. F. Martyn has also contributed an article in the Phil. Mag. on frequency variations in valve oscillators.

Highly accurate wavemeters of the self-oscillating type are available, as made by instrument-making firms. Those of continuously variable type over a long range attain an accuracy of about 3 parts in 10 000, whilst specially adjusted instruments to cover only a limited range attain an accuracy and permanence of 1 part in 10 000.

The resonant type of wavemeter has also received much attention at the hands of one instrument firm who has developed accurate variable air condensers (of which more will be said later), and inductances so designed that the whole instrument has a very small temperature coefficient and also remains constant with time. Such wavemeters are somewhat bulky but retain their calibration accuracy to about 1 part in 10 000. The Marconi Co. has also developed station wavemeters of the resonant type, and has reached a good state of perfection mainly by attention to mechanical principles in the design. These wavemeters, specially suited to short wave measurements, are mounted in temperature regulated glass-walled enclosures which ensure a permanence of calibration accuracy to about 1 part in 10 000.

Wavemeters of the resonant type, as described above, are also used sometimes with a valve circuit connected to the wavemeter, so as to produce the least disturbance on the resonant frequency or used as a negative resistance to maintain oscillations in the wavemeter without the use of auxiliary inductances.

Quartz Resonators.

As adjuncts to provide fixed frequency points in conjonction with resonant wavemeters, the familiar type of quartz resonator is sometimes used. It cannot be said, however, that the practice has been developed to the extent which would be justified by the great accuracy, portability and convenience of the quartz resonator. The luminous types of resonator mounted in a glass bulb in an atmosphere of a mixture of helium and neon, under reduced pressure, are particulary satisfactory types of resonator, much used in Germany, but only very seldom seen in this country. There is no doubt from the writer's experience of these resonators, that they are capable of providing a known frequency in an independent valve oscillator to an accuracy of about 1 part in a hundred thousand.

A number of international frequency measurements have been made from time to time during the past three years and are detailed in a separate Appendix (¹).

2. CURRENTS AND VOLTAGE.

Advances have been made in current measurement particularly at very high frequencies. E. B. Moullin has perfected an instrument which is electro-dynamic in principle. The repulsion between two parallel conductors carrying the same current is the actual means used to observe and measure the current. The design is such that calculations of all the factors which enter into the expression for current can be calculated. These factors include, of course, the main term and a number of terms involving the distributed capacity, inductance and effective resistance of the active conductors. These can all be calculated or measured, and the correction terms be

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(¹) See p. 27.

thereby determined. In a modified form for larger currents, the difficulties of leading the current into and out of the moving conductor have been overcome by using the principle of mutual induction into the moving element. The moving element is a cylindrical tube mounted excentrically with respect to an enclosed fixed conductor which carries the current. The whole is enclosed in oil for damping and cooling purposes. The accuracy is stated to be about 1 % at frequencies as high as 30×10^6 cycles per second.

Another type of extra high frequency ammeter developed by C. C. Fortescue, utilises the thermal effect of current. The form of this instrument is that of a wire concentrically mounted in an enclosing tube. The measurement is made by expansion of the wire. Currents larger than that permissible in a single wire, are measured by using a cylindrical cage arrangement of identical wires and tubes, care being taken to ensure symetry in the end connections. The expansion of one wire is used in measuring the current.

The system lends itself to a comparatively simple calculation of the correction terms depending upon distributed inductance and capacity and skin effect in the wire, The latter term is, of course, of great importance. Currents of frequency as high as 100×10^6 have been measured by such devices, but one of the great difficulties encountered has been to devise circuits by which different current measuring instruments can be compared. The bridge system adopted would appear to be very satisfactory in this connection.

At the National Physical Laboratory work has been done following up that carried out some years ago on a mercury coil in glass tubing. The arrangement for current measurement consists of a straight glass tube filled with mercury and enclosed in a concentric return tube. A capillary tube communicating with the mercury, serves to indicate, by the expansion of the mercury, the current.

An alternative method uses two cylindrical conductors contained in two concentric shields and compares the differential expansion when alternating current is sent through one and direct current through the other; by such comparative measurements, thermal effects, other than those due to the currents, are eliminated.

Work is in progress in connection with all these methods and developments may be expected in the near future after intercomparison measurements, also in progress, have indicated what are the probable errors associated with each. Other methods utilise the thermionic emission of a valve. The filament of the valve is used as the current-carrying element and the emission is used to measure the current.

But little work has been done upon current transformer or condenser dividers for measurements of large currents at extra high frequencies, but transformers with air core have been used successfully at frequencies of 10×10^6 cycles per second, and condenser dividers have been developed for currents of 50 amperes at frequencies up to 5×10^6. The residual inductances of condensers fixe the present limit of frequency at which they can be used in parallel for purposes of current subdivision for measurement purposes.

Experiments on current measurement by utilisation of the potential difference at the ends of a suitable resistance unit have been made at the N. P. L. using a valve to measure the method gives very good agreement with thermo-junction methods up to 2×10^6 cycles per second, but divergences occurred from this value up to 10^7 cycles per second. Various differences were obtained with various types of thermo-junction, the indications being that the valve method is at least as satisfactory as the thermo-junction method, with the advantage that greater sensitivity can be obtained if desired.

In connection with the measurement of very small voltages, as in field intensity measurements, etc., advances have been made in the means used to calibrate such apparatus. Screened oscillators and attenuators have been designed and proved satisfactory for frequencies up to 20×10^6. In some forms the attenuator consists of a transmission line of concentric form for which the calculations can be made with accuracy. In others, as in a portable intensity measuring set for frequencies from 5 to 12 mega-cycles per second, resistance attenuation is used and the mutual inductances are of toroidal form.

The valve voltmeter has been investigated fairly fully and its possibilities and limitations are known. Moullin has developed a peak voltmeter operating by the principle of cumulative grid rectification, the mean grid potential being equal to the peak value of a sine wave of applied voltage. By the emission of the grid condenser, the apparatus is converted to a mean voltmeter. The instrument has an input resistance of about 1.5 megohms and depends for its calibration upon the constancy of this resistance.

The copper oxide rectifier has also been applied commercially to the construction of milliammeters for alternating current. Such instruments read the mean rectified current but since at high frequencies, wave distortion is not very great, the readings may be taken as proportional to root mean square values also. Hartshorn has investigated the behaviour of such instruments and has found that considerable errors occur due to the resistance of the instrument varying with current passing throught it, and at the same time the rectifier behaves as if shunted by a condenser of considerable capacity. It was found possible to compensate these errors by the use of an inductive shunt satisfying certain relations. The errors were reduced in a typical case from 30 % between 50 and 10 000 cycles per second, to a negligibly small amount.

3. CONDENSERS AND INDUCTANCES.

Progress has been made in the design and construction of these essential adjuncts to radio frequency measurements. For wavemeter purposes, special variable condensers of great permanence have been constructed embodying the principle of two condensers in series. These condensers have a moving system of thick plates not connected to the terminals, but serving to take up the space between other fixed banks of plates forming tho actual capacity. The system is thus equivalent to two condensers in series and hence a considerable axial displacement of the moving system causes no change in effective capacity. By careful attention to the form and disposition of the insulating material, the temperature coefficients of such condensers can also be made very small.

Such condensers retain a calibration accuracy of at least one part in 5 000, and used as the capacity element of resonance, wavemeters allow of an accuracy and permanence of frequency calibration to 1 part in 10 000.

Other special. types of condenser developed for short wave wavemeters and for giving very small capacity changes on an open scale, are made in the form of one cylinder mounted excentrically upon an axis parallel with and excentric to the axis of another cylinder within which it is contained. The cylindric surfaces can be produced with good accuracy, and the law of capacity variation be determined by calculation. Capacity changes as small as 0.001 $\mu\mu$ F. may be read upon such condensers.

For purposes where capacities are required to be made exceedingly small, in connection with coupling systems for attenuation, etc., condensers embodying a sliding or turning member operating in front of an opening between two compartments, have been used. By such means, a variable capacity of range down to zero value may be obtained.

The development of bridges. with Wagner earthing arms for radio frequency measurements, has made possible the use of standard variable air condensers of three-terminal type in which the two working electrodes are each supported upon quartz or other insulating material, directly upon a base plate forming part of the independent screen. In this way all dielectric losses are transferred to the auxiliary capacities between each element and earth. The effective working capacity is, therefore, free from all dielectric losses and by suitable design of the plate system can be made to have unmeasurably small conductor losses. Such condensers are to all intents and purposes perfect from a loss point of view and serve as primary standards of capacity. Such condensers are in regular use at the N. P. L. and have proved very satisfactory.

Inductance coils for wavemeter purposes have also received attention at the hands of instrument makers, and have reached a considerable degree of perfection in respect of temperature coefficient and freedom from effects of humidity. These results are obtained by choice of suitable insulating materials of different thermal expansions which, by a differential expansion effect, cause a compensation of the changes in inductance due to changes in diameter and axial lenght of the coils.

In apparatus used in connection with work where shielding is necessary, there is a growing tendency to use toroidal coils. The design of these is well worked out and after allowing for the considerable increment in resistance of ordinary cylindrical coils when enclosed in an effective shielding box, the toroidal form are not sensibly greater in effective resistance for the same overall dimensions.

4. GENERAL MEASUREMENTS AND PROPERTIES OF CIRCUITS.

There has been a very great development in the applications of radio frequency to all kinds of measurements and it is, of course, impossible to give a very clear perspective of the present position.

Considerable advances have been made in the use of bridge networks at radio frequencies; such bridges are in use at the Post Office, and at the laboratories of the Standard Telephones & Cables Co., following the principles of G. A. Campbell whereby each arm is independently double-screened. At the N. P. L. much time has been spent upon a Schering Bridge for accurate measurements upon dielectrics, condensers and other inpedances at radio frequencies up, to 2×10^6 per second. In this bridge the phase angle of condensers can be measured to an accuracy of about 3×10^6 radian. The bridge is provided with a Wagner earthing network and the conditions enabling a rapid convergence of the alternate bridge and Wagner balances to be obtained, have been worked out. This feature is of great importance and is one of the governing factors, making it possible to use a Wagner device at radio frequencies. With such a bridge, special three-terminal condensers with independent screen may be used as indicated in the section under condensers.

The losses in high class variable air condensers of the usual two-terminal type, can be measured with good accuracy in terms of such standards on a bridge of the kind developed at the N. P. L., and many condensers have been so measured and their losses have been analysed into their respective components.

Completely satisfactory electrode systems have been evolved for accurate measurements of power factor of dielectrics of all kinds in sheet form, using mercury electrodes. Other applications of the bridge are to the direct measurement of impedances of radio frequency chokes, valve element impedances as well as effective resistance of inductive coils of normal kind.

Sutton has carried out experiments on condensers by the use of a principle of similitude in which the condensers are immersed in a conducting liquid. By analysis of the results obtained with air and with the conducting liquid as dielectrics, at various frequencies, it has been found to separate out and determine the components of loss in the air condenser due to conductor and dielectric respectively. Sutton has also carried out measurements of power factor and capacity of the electrodes and bases of various valves, and has shown the importance of an accurate knowledge of these in cases of valve voltmeters and other measuring devices where valves are used.

Mutual inductances which are variable, have been used for high frequency resistance measurements on coils by circuit arrangements which avoid a knowledge of the power factor of variable condensers.

The use of frequency change in various wireless measurements is coming more and more into use, as the peculiar advantages of frequency are being realised. Thus Colebrook and others have shown the convenience and accuracy of methods based on those originally developed by Willans in which the resonant circuit under measurement has no measuring devices connected to it. The circuit is coupled to an oscillator and the frequency changes observed as the tuning capacity in the oscillator is varied through resonance of the circuit. From observations of the instantaneously stationary values of the frequency, the constants of the circuit may be determined. Good accuracy up to frequencies of 10 megacycles per second has been obtained. The normal resistance variation methods of effective resistance measurement have also been found quite satisfactory at frequencies of 10^7 cycles per second.

Numerous investigations have been made upon valves both on the theoretical and on the experimental sides; it is impossible to refer to these in any detail. They include theoretical investigations into rectification and generalised analysis of triode valve equivalent net works, filter systems, including valves in which filtering and amplification are combined. The measurements of the effective grid-filament and anode-filament impedances of three and four electrode valves have been investigated at telephonic and at radio frequencies. New methods have also been evolved for the measurement of the residual capacity between working grid and anode of screen-grid valves; examples of capacities as small as 0.0014 $\mu\mu$ F. have been found. The measurements can now be made to an accuracy of about 0.00005 $\mu\mu$ F. at radio frequencies. In one such method used at the N. P. L. the change in effective grid-filament input impedance of the valve resulting from a change from zero to a large anode impedance, is used as a measure of the effective grid-anode capacity, and since an amplification of several hundreds as given by the valve itself is operative, very good sensitivity can be obtained under working conditions.

D. W. Dye., D. Sc., F. R. S.

APPENDIX TO REPORT OF COMMISSION I.

RADIO FREQUENCY INTERNATIONAL. COMPARISON MEASUREMENTS 1928-1931 (¹)

The proposals originally made at Brussels in 1928 were that three methods of intercomparison should be used, viz.,

(*a*) Simultaneous measurement of the U. S. Naval Short Wave Station at Arlington.

(*b*) Circulation of Piezo-Electric Oscillators.

(*c*) Transmissions of telephonic frequency modulations of accurate known values superposed upon a carrier wave of convenient value.

(*a*) **Simultaneous Measurements.**

These methods were all followed up but, unfortunately, the first met with very little success. The programme arranged a first by the short wave station was not well received in Europe including Great-Britain. A second programme was arranged at a more suitable time of day for the transmissions but, unfortunately, was sent out on a day of the week other than that arranged. In addition, an Italian station of almost identical wave length caused serious interference.

Further transmissions under improved conditions were promised but, up to the time of writing, these have not been announced.

In the meantime, announcements of specially constant transmissions from the Bureau of Standards Washington, at 5 000 kc/s. have appeared and show great promise of their suitability for international comparison purposes, if not too weak.

Information will be forthcoming shortly upon the reception conditions at the N. P. L. in regard to this transmission.

The only measurements successfully made in England on the Naval Station at Arlington were made by the Post Office and gave agreement to about 2 parts in a million with the Washington values.

In 1930 measurements on several occasions on the Eiffel Tower transmissions were made in France and in England and gave the mean results

Paris	207 398 kc/s.
N. P. L.	207 402 kc/s.

The mean variation from the mean attributable to the station variations in frequency was $\pm 4 \times 10^{-5}$ or twice as great as the mean difference between the two countries.

(*b*) **Piezo-Electric Oscillators.**

At the time of the previous report, two of these have been circulated from the Bureau of Standards. These were not temperature-controlled and were measured at different tempera-

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(¹) See p. 23.

tures in different Laboratories. The results on these oscillators showed clearly that they were unequal to the task of really comparing the national standards, the differences observed amongst five laboratories had a mean value of $\pm 2.5 \times 10^{-4}$ in frequency.

In 1929 a more perfect form of oscillator with temperature control was circulated by the Bureau of Standards; this oscillator gave very much reduced differences. The mean variation from the mean in five laboratories was $\pm 3 \times 10^{-5}$ with the N. P. L. values at -4×10^{-5} from the mean and -3×10^{-5} from Washington. The differences in frequency between the values at Washington before departure and after return from its circulation amounted to 2 parts in 100 000.

Later in 1929 another temperature-controlled quartz oscillator brought by hand from the B. S. was measured in France, Italy, Germany, Great-Britain and U. S. A. The mean variations from the mean of all measurements made were — 24, — 29, + 15, + 6, + 31 parts in 10^6 respectively, showing an improvement over the previous measurement.

In 1931 a quartz oscillator was brought over from Paris by M. Jouaust in connection with international comparison work entrusted to him on behalf of the Comité Consultatif Internationale Radio. This oscillator was of very good design, stability and reproducibility, except for one occasion when it developed another mode of vibration. The oscillator has been measured in France, Germany and Italy but the complete results are not yet available. Those between France and England gave the result

Paris	162 052.7 cycles per sec.
N. P. L. . . .	162 052.8 cycles per sec.

This result is exceedingly satisfactory for a measurement on a portable oscillator. The variation before and after the journey between Paris and London was about 2 parts in 10^6. Observations made upon this oscillator when running in the steady state, showed continual very small variations in frequency suspected to be the result of small movements of the crystal resulting from the vibration. The mean variations in frequency thus observed was just 1 part in a million. In a valve source used in connection with the measurements, the mean variations — if real — were less than 2 parts in 10 million. The extreme agreement between the two measurements at the two laboratories on this oscillator must be regarded as accidental.

Quartz Resonators.

Some experience has now been gained in the use of quartz resonators as frequency standards suitable for intercomparison purposes. In 1929 M. Jimbo brought from country to country a luminous resonator of the kind developed in Germany. This was measured in many laboratories and very good agreement was obtained. The mean variation from the mean frequency was only 15 parts in 10^6 on a frequency of 10 000 cycles per second, which the bar vibrating flexurally had as its fundamental of that mode.

In February 1931, M. Jouaust brought over a resonator of Giebe type, of frequency 100 000 cycles per second, and this resonator was measured at a number of European national laboratories. The complete results are not yet available but between England and France the results were

Paris	99 975.9 c/s.
N. P. L.	99 976.0 c/s.

again showing a good agreement. These resonators are not temperature-controlled and the condition of resonance is observed visually by a glow which appears at the stressed regions of the resonator. With temperature control, and more sensitive and accurate means of observing resonance, it is believed that such resonators would be capable of giving comparisons to one or two parts in a million.

(*c*) Telephonic Modulation.

The idea of utilising a telephonic standard frequency modulation on a carrier wave originated with the writer on the occasion of the last meeting of the U. R. S. I. and since that time various tests of the principle have been made both at the N. P. L. and in Paris by M. Jouaust who has adopted the idea on behalf of the C. C. I. R.

The first measurements made were on transmissions from the Eiffel Tower in 1930 using a fork of 1 024 c/s. frequency on the carrier wave of 207.4 kc/s.

Four separate series of transmissions were made and gave results at the N. P. L. 1 024.089, 1 024.052, 1 024.078 and 1 024.043. The corresponding measurements in Paris were 1 024,091, 1 024.089, 1 024.072 and 1 024.046 cycles per second. The measurement in Paris, 1 024.072, was considered less accurate than the others owing to stoppage of the phonic wheel. The means, neglecting this measurement, are in agreement to less than 1 part in a million. But the mean variation is ± 2.5 parts in a million which represents more closely the probable accuracy of the comparisons. Small drifts of frequency amounting to about 3 parts in a million, occurred during an hour's transmission.

Quite recently the B. B. C. station 5XX at Daventry, has transmitted a modulation at 1 000 c/s. on a carrier frequency of about 193 kc/s. The measurements on this, made in Paris, Post Office and N. P. L. gave mean results

Paris	1 000.049 cycles per sec.
Post Office . .	1 000.043 cycles per sec.
N. P. L. . . .	1 000.042 cycles per sec.

The Paris measurements are open to confirmation, and it is thought that the difference from the English measurements is larger than experimental errors. Other comparison measuments were made on this transmission but they are not yet available.

It is hoped to continue these transmissions as a programme once a month on Tuesday mornings. Future transmissions will be more constant than this first one, which showed a drift of about 6 parts in 10^6 during the hour. The tuning fork was not temperature-regulated and would easily account for such drift.

In general, it may be said that transmissions of both kinds and quartz oscillator and resonator standards vie with one another in their improved operation in trying to keep pace with the greatly improved national standards during recent years.

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COMMISSION II. — PROPAGATION DES ONDES.

COMMISSION II. — RADIO WAVES PROPAGATION.

INTRODUCTION.

La Commission de la Propagation des Ondes est composée des membres suivants :

The Commission on Radio Wave Propagation is composed of the following members :

Président :	M. le D^{r} L. W. AUSTIN, du Laboratory for Special Radio Transmission Research, Bureau of Standards.
Belgique :	M. le Prof^{r} Th. DE DONDER, Membre de l'Académie Royale de Belgique, Professeur à l'Université de Bruxelles; M. le Prof^{r} Fr. VAN DEN DUNGEN, Professeur à l'Université de Bruxelles et M. le Prof^{r} G. VAN LERBERGHE, Professeur à l'Ecole des Mines de Mons.
États-Unis :	M. le D^{r} L. W. AUSTIN.
France :	M. le Prof^{r} MAURAIN, Directeur de l'Institut Physique du Globe et M. le Prof^{r} R. MESNY, Professeur Principal d'Hydrographie, Professeur à l'École Supérieure d'Électricité de Paris.
Grande-Bretagne :	M. le Prof^{r} E. V. APPLETON, Wheastone Laboratory, King's College; M. O. F. BROWN, Department of Scientific Research; M. le Capitaine P. P. ECKERSLEY, British Broadcasting Corporation; M. le D^{r} E. H. RAYNER, D. Sc., National Physical Laboratory; M. le D^{r} F. E. SMITH et M. le D^{r} R. L. SMITH-ROSE, D. Sc., Ph. D., D. I. C., A. M. I. E. E., National Physical Laboratory.
Italie :	M. le Commandant C. MATTEINI; M. le Major Chevalier A. MARINO, Direction Supérieure d'Études et de Recherches de l'Aéronautique et M. l'Ingénieur V. GORI.
Japon :	M. T. HAYASHI, Military Signal School; M. T. NAKAGAMI, Bureau of Telephone and Telegraph Engineering, Ministry of Communications; M. le Rear-Admiral K. NISHIZAKI, Naval Technical Deparment, Ministry of Navy; M. Y. TAKATA, Broadcasting Corporation of Japan et M. E. YOKOYAMA, Electrotechnical Laboratory.
Norvège :	M. T. ENGSET, Directeur Général de l'Administration des Télégraphes; M. F. GYTHFELDT, Ingénieur à l'Administration des Télégraphes et M. le Prof^{r} H. PEDERSEN, Ingénieur en Chef de l'Administration des Télégraphes.
Nouvelle-Zélande :	M. le D^{r} M. A. F. BARNETT, Department of Scientific and Industrial Research.
Pays-Bas :	M. le Prof^{r} D^{r} Jhr. G. J. ELIAS et M. le D^{r} B. VAN DER POL, du Natuurkundig Laboratorium des N. V. Philip's Gloeilampenfabrieken.
Portugal :	M. le Capitaine de Corvette E. M. SOARES, Instructeur de Radiotélégraphie à l'École des Torpilles et d'Electricité de la Marine.
Suisse :	M. le D^{r} J. LUGEON.

COMPTE RENDU DES SEANCES. — ACCOUNT OF THE MEETINGS

SÉANCE DU SAMEDI 30 MAI. — MEETING OF SATURDAY, MAI 30th.

La séance est ouverte à 16 heures sous la présidence de M. le Dr. L. W. Austin. M. le Profr E. V. Appleton est désigné comme Vice-Président et M. le Profr Mesny comme Rapporteur.

Le *Général Ferrié* demande la parole et souhaite la bienvenue au Profr Wagner qui a bien voulu venir prendre part aux travaux de l'U. R. S. I.

Le *Profr Mesny* donne ensuite lecture de la proposition française relative aux mesures régulières à entreprendre dans tous les pays sur la hauteur de la couche de Kennelly-Heaviside (¹).

Profr Appleton remaks that actually the participation of eight measuring stations might be expected : one in China (Shangaï), two in Germany, one in Great-Britain, one in France, one in Poland and two in the United States.

Happily the two most used methods : that of frequency change and that of group retardation measure the same quantity, so that each station may use whichewer of the two methods is more convenient.

It would be very desirable to carry out the measurements on two waves round 80 and 170 metres, with a view of obtaining data on the two Kennelly-Heaviside layers.

These measurements should be made every week at midnight local time on the Wednesday and at midday on the Thursday.

Le *Général Ferrié* se rallie aux propositions de M. le Profr Appleton, mais comme il pense qu'il n'y a pas plusieurs couches distinctes mais un milieu dont l'ionisation varie de façon continue, il estime que l'on devrait plutôt faire varier la longueur d'onde employée d'une façon continue autour de sa valeur moyenne. On verrait ainsi si l'on n'obtiendrait pas des variations continues de la hauteur mesurée.

Profr Appleton thinks that this method would be too laborious for general use, and that it is unnecessary for the following reason. In his own experiment he has already shown that a continuous variation of frequency shows only very small variations of the effective height until a critical frequency is reached near which a very small change of wavelength shows a very considerable increase in effective height, this new height being about twice the original height. If the frequency is still further reduced, the variations of this new height are again very small.

Dr van der Pol thinks the two points of view may be defended and since the nature and disposition of the layers may vary with latitude, he suggests that both methods should be used.

The *Chairman* declares discussion on this closed point and asks if Profr Appleton would undertake to organize the work and to collection the results.

Profr Appleton agrees with this want.

The *Chairman* proposes the appointment of a sub-commission to study the inter-relations of radioelectric, physical and astronomical phenomena in connection with the problems of the upper atmosphere. Professors Appleton and Chapman, nominated by the Chairman, agree to act as a sub-commission for this purpose.

Le *Rapporteur* donne ensuite lecture de la deuxième proposition française (¹).

Profr Chapman agrees with this proposal.

(¹) Annexe I, p. 38.

(¹) Annexe I, p. 38.

The *Chairman* remarks that the American National Committee has examined the question and is not very favourable to the present proposal, as the Committee is doubtful of the value of measurements of intensity vatiations, especially for long waves whose variations are often of little importance. This Committee is also alarmed at the prospect of an accumulation of a great mass of numerical data.

He proposes that the French National Committee should be asked to carry out work of this character for a trial period of a year before any general action is taken.

Le *Général Ferrié* accepte pour le Comité National Français.

Dr. Smith-Rose announces that the British National Committee hopes that the British authorities will, at their own expense, send out a Polar Year expedition to carry out measurements on the effective height of the Kennelly-Heaviside layers and on the distribution of ionisation in them. It would be very desirable that other countries should do the same, and in particular, that the American National Committee should carry out work if this kind in North America, near the magnetic pole.

Prof^r^ Appleton gives some details on the British expedition; it is hoped to send three workers for a period of three months beginning in the University vacation of 1932.

He suggests that the American National Committee may obtain assistance and support from the Rockfeller or Carnegie Foundations for work of this kind.

Prof^r^ Pedersen announces that probably a Danish mission will be sent out, but it is not yet certain.

Dr. van der Pol makes a similare statement for Holland.

Le *Général Ferrié* indique que la France enverra une mission et que, si la nature du personnel qui y participera le permet, on pourra aussi faire des mesures sur la hauteur de la couche de Kennelly-Heaviside.

Prof^r^ la Cour regrets not to be able to give preuse information upon the various missions, he has not yet received definitive reports.

He suggests the appointment of a sub-commission, to which he undertakes to communicate all the information he receives on the subject of the Polar Year programme.

Le *Général Ferrié* estime que cette Sous-Commission ne devra pas borner son travail aux prévisions relatives aux mesures de la couche Kennelly-Heaviside, mais l'étendre aux phénomènes de propagation et des atmosphériques. Elle devrait donc comprendre des spécialistes de ces questions.

The *Chairman* then suggests the appointment of a commission of five Members of which M. la Cour should also be a member. Commissions III et IV would each present another.

Le Prof^r^ Appleton est désigné pour la Commission II.

Dr. van der Pol remarks that it would be very desirable that the sub-commission should draw up instructions for the staff of the mission, a staff which ought to be formed beforehand.

Prof^r^ Appleton thinks it would require about two months to train a graduate in sciences for these measurements; an ordinary assistant is not sufficient.

The *Chairman* remarks that the discussion on this subject is exhausted and begs M. Braillard to read his work on « Contribution à l'Étude des Lois de Propagation des ondes hertziennes dans la gamme de 150 à 1500 kc/s. » (¹).

After this communication, the Chairman says that he finds it remarkable that such a limited number of observations has given so regular curves.

Dr. van der Pol remarks that in this work only maximal values of the fields have been considered.

M. Braillard donnera dans sa note toutes indications de détail relatives aux observations particulières pour éliminer toute incertitude sur les résultats d'ensemble.

(¹) Annexe II, p. 39.

SÉANCE DU JEUDI 4 JUIN. — MEETING OF THURSDAY, JUNE 4th.

La séance est ouverte à 10 heures sous la présidence de M. le Dr. Austin.

The *Chairman* summarises the contents of his report on relations between propagation and solar activity (1).

Dr. Watson-Watt points out that observations on atmospherics add to the data available on these relationships. For example during atmospheric observations thourought Western Europe, upon frequencies from 200 to 800 kc/s., only once on seventeen days of observation, was a total absence of atmospherics found simultaneously at nearly all the stations; the intensity of atmospherics remained much below 1.1 mv/m. during the ten minutes of observation. The phenomenon occured on the day of a great magnetic disturbance.

On the other hand, for observations on 10 kc/s., he had found that during magnetic disturbance the usual regular curve is followed for most of the time, but that sometimes the intensity of atmospherics increases suddenly and remains on a high level for 20 to 30 minutes (2); those peculiarities seem to be produced when the time rate of change of the vertical component of the magnetic field is a maximum (This component was arbitrarely taken as an index of the magnetic activity, as a matter of convenience, in the case examined).

Le *Dr. Lugeon* a observé les mêmes phénomènes sans se les expliquer.

Le *Commandant Bureau* fait remarquer qu'il est étrange de constater, d'après les observations du Dr. Austin, que les atmosphériques diminuent, et que le champ des ondes augmente quand l'activité solaire croît. Il semblerait que les atmosphériques devraient augmenter quand la propagation devient meilleure. Sinon, cela prouverait que l'activité solaire agit non seulement sur la propagation, mais sur les sources d'atmosphériques et que celles-ci perdent de la puissance quand l'activité solaire croît.

Profr Appleton referring to M. Austin's own work remarks on the necessity for runs of data of long duration with a view to finding correlations. He thinks that purely local observations like those on the height of the Kennelly-Heaviside layer may more easily reveal the instantaneous correlations with the magnetic perturbations observed a the place of observation.

Dr. Rayner thinks it might be interesting to make atmospheric observations on very low frequencies, corresponding to waves of 200 km. for instance.

Dr. van der Pol incidentally asks what are the shortest waves capable of beeing used for long distance communications.

Profr Appleton mentions 17 metres during the night and occassionally 8 to 9 metres during the day.

The *Chairman* says that the Radio Corporation has been able during short spaces of time to obtain communications on 8 metres between United States and South America.

Profr Appleton mentions a very important subject for study : Why are the short waves so advantageous? He recalls the curve given by Taylor and Hulburt for the ranges of a wave as a function of its frequency for a given antenna power. This curve shows a minimum round the frequency of 1 500 kc/s. (200 metres) and it has been thought that this minimum was due to the terrestrial magnetic field which might produce a resonance, but he does not think that this is the true cause of the phenomena. If however, this is not the cause, then what is the cause?

Le *Profr Wagner* rappelle que Meissner a fait des expériences soignées pour chercher à mettre en évidence ce minimum et qu'il n'a rien trouvé.

Dr. van der Pol says that the data are not usually given with sufficient precision, in particular the power quoted is always antenna power and there are no data concerning the effective radiated powers.

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(1) Annexe III, p. 52.

(2) *U. R. S. I. General Assembly held at Brussel, in 1928*, fasc. I, p. 129, fig. 9.

The *Chairman* calls attention to the experiments of Anderson of the Bell Telephone Company. These experiments on short and long waves over the Atlantic have shown that the measured fields were included between those calculated from the Austin formula and from the inverse distance law.

Le *Prof^r Wagner* signale que les mesures faites en Allemagne sur les stations de radiodiffusion à des distances allant jusqu'à 1.000 km. ont donné de jour des valeurs du champ correspondant à la loi exponentielle pour la distance, mais avec un coefficient exponentiel supérieur à celui d'Austin. Les champs de nuit ont toujours été trouvés inférieurs à ceux que donnait la loi de l'inverse de la distance.

Dr. Rayner asks from what direction the waves reach the receiving apparatus. How would they be seen it they were visible? Like a spot in the sky or in diffuse way? In other words might one legitimately speak of rays?

Dr. van der Pol says that according Eckersley the waves are propagated by successive reflexions between the earth and the Kennelly-Heaviside layer. Eckersley sent across the Atlantic a very short signal. Several signals (two to six) were obtained at the receiving stations and from the intervals of time between the signals it has been deduced that several rays were propagated by several reflexions above and below. Does not this phenomenon appear inadmissible owing to absorption during the reflexions at the earth?

Prof^r Pedersen agrees with Dr. van der Pol.

Le *Général Ferrié* indique qu'on a fait des constatations du même genre sur les signaux horaires transmis entre Paris et Saïgon.

Dr. van der Pol wonders if the question at issue is not a purely verbal one. The first point is wether it is permissble to speak of rays; Professeur Manneback of the University of Louvain has studied the question and has come to the conclusion that one may speak of rays only if the gradient of the dielectric properties as a function of λ is very steep when passing from one medium into another. Therefore he concludes that the best thing to do is to sit down at our study tables to consider the conditions at the boundary.

Le *Dr. Lugeon* pense qu'on doit étudier la propagation des ondes courtes en tenant compte de la surface limite de l'ombre et de la lumière au-dessus de la terre. Il a examiné de cette manière des séries d'observations transatlantiques sur 14 et 23 mètres, publiées récemment, et constaté qu'il y a communication ou non suivant que les rayons rasants du soleil se trouvent, sur le chemin de l'onde, au-dessus ou au-dessous d'une certaine altitude.

The *Chairman* brings into the discussion the subject of echoes of long delay.

Dr. van der Pol recalls the conditions in which they were observed and the explanation he gave in « Nature ». This explanation is based on the consideration of the velocity of signals groups. It has been argued againts his explanation that if the waves stayed so long in an ionised medium they would be completely absorbed, but this objection is not serious because the height of reflexion is not known; the absorption might be very small. The earlier experiments of Quack on waves travelling several times around the earth and those made more recently in Japan show that the waves might stay a long time in the atmosphere and still retain a notable amplitude. It must be remembered that the echoes he has observed are very rare and that they probably want very special conditions in the atmosphere.

The explanation of Störmer is also not free of objections, even the existence of his electron streams is uncertain, for he did not take in account the repulsives forces which would spread them out, for they produce more intense effects than the terrestrial magnetic field.

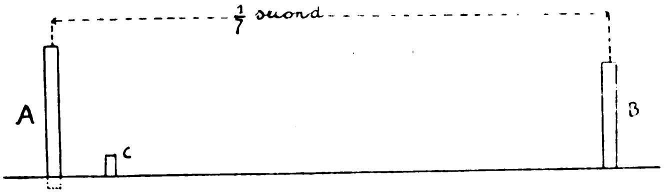
Dr. Rayner thinks that owing to the fact that echoes are very rare phenomena it ought to be seen if the dates when they were observed do not correspond to very particular conditions.

SÉANCE DU SAMEDI 6 JUIN. — MEETING OF SATURDAY, JUNE 6th.

La séance est ouverte à 10 heures sous la présidence de M. le Dr. L. W. Austin.

Dr. van der Pol gives an account of the very interesting experiments recently carried out by Dr. Mogel. He sent out from a vertical antenna very short pulses of the order of the thousandth of a second and he received them on a neighbouring antenna, at first vertical then horizontal.

In the first case a first signal A (see fig. 1) was registered and a second one B of the same value, 1/7 second later, the time required by the wave to go round the earth. Besides, a short signal C was registered at a distance from A equal to about one tenth of AB.



Reception on a vertical antenna

FIG. 1.

With reception on the horizontal antenna, two signals A' and B' (see fig. 2) corresponding to A and B were still received, but instead of signal C a long trace beginning somewhat earlier than C. The oscillograph used had a natural frequency of about 10 000 c.s. These results seem to bring into in evidence the influence of group-velocity. Besides, as shown by Dr. Joos, a sprading out of the signal is to be expected in these conditions, a phenomenon due to the dispersive properties of the medium; the record of figure 2 would agree with these considerations.

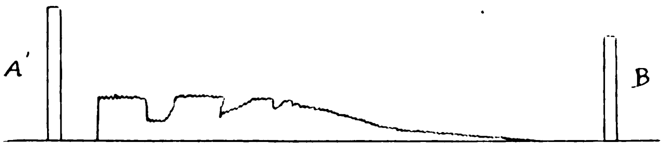
Dr. van der Pol cites in connection with this subject the results he has obtained with delayed echoes. These echoes aurally observed were spread out and dissimilar to the emitted signals.

Le *Prof^{r} Wagner* estime que l'explication de M. van der Pol est correcte et rapproche ces phénomènes de ceux observés dans la téléphonie avec fil à grande distance. Il serait désirable de recevoir de tels échos sur plusieurs récepteurs sélectifs accordés sur des fréquences différentes pour apprécier la dispersion; des observations de ce genre pourraient confirmer l'origine du phénomène.

Il signale d'autres expériences d'échos faites en Allemagne, au cours desquelles, en admettant pour vitesse des ondes la valeur c dans un milieu non-ionisé, on trouvait avec une onde courte une couche réfléchissante située à 2.000 kilomètres de hauteur environ. Avec une onde plus longue, cette hauteur était de l'ordre d'une centaine de kilomètres. Dans le premier cas on a souvent observé plusieurs échos qui correspondaient à des chemins parcourus multiples exacts de celui assigné au premier.

Il pense que la hauteur où se produit la réflexion dépend de la longueur de l'onde.

Dr. van der Pol wishes to emphasise the smallness of the loss of power often found in short wave propagation. In the experiments made by Mogel, the signal produced by a wave which had been five times round the earth was still represented on the oscillogram by a deviation equal to one tenth of the first deviation, the detector used following a square law.



Reception on a horizontal antenna

FIG. 2.

The *Chairman* asks if these long journeys are believed to be due to multiple reflexions.

Le *Prof^{r} Wagner* estime que cela donnerait lieu à des pertes d'énergie inadmissibles et il rappelle la théorie de Lassen selon laquelle il existerait une distance zénithale des rayons pour

laquelle ceux-ci pourraient se propager à une hauteur constante et par conséquent se propager à de très grandes distances sans prendre contact avec le sol.

Prof^r Appleton asks how then these rays can come back to earth.

Le *Prof^r Wagner* pense qu'ils peuvent céder en chemin une partie de leur énergie par une sorte de diffusion. Il signale que des expériences faites en aéroplane montrent que l'énergie reçue croît beaucoup avec la hauteur au-dessus du sol.

Le *Prof^r Mesny* fait remarquer que dans ces conditions on conçoit mal que les signaux reçus à grande distance aient une énergie d'un ordre de grandeur comparable à celui des signaux à courte distance. On pourrait encore penser que les différents rayons dont la distance zénithale est voisine de celle mentionnée par M. Wagner atteignent le sol à des distances de plus en plus grandes de façon à ramener d'une manière à peu près continue aux différents points de la terre, l'énergie émise.

Le *Prof^r Wagner* fait remarquer que les signaux ne se propagent aussi facilement autour de la terre que quand tout le chemin qu'ils peuvent parcourir sur un arc de grand cercle est éclairé par le soleil.

Dr. van der Pol draws attention to the acoustic analogy with a « whispering gallery » in which a weak sound sent in a direction tangential to its wall goes easily round.

Dr. Rayner asks if these phenomena are obtained only when the receiving set is in the neighbourhood of the emitting station. What would happen if the stations were distant from each other?

Le *Prof^r Wagner* répond que les signaux faisant le tour de la terre ont aussi été observés dans des expériences faites entre Buenos-Ayres et Nauen.

Le *Dr. Lugeon* pense qu'il serait intéressant de chercher à obtenir des échos sur la surface de séparation de la lumière du soleil et de l'ombre de la terre, région dans laquelle l'atmosphère ionisée présente une variation importante.

Dr. van der Pol alluding to the experiments mentioned above and carried out by M. Mogel remarks that similar methods could be used to determine the composition of the ionized layers. To study an amplifying apparatus without examining the internal elements, sinusoïdal electromotive forces of various frequencies can be applied to the input and what comes out of the apparatus measured, knowing the intensity at the output and the phase of every signal as a function of the corresponding signals at the entrance, it would be theorically possible to determine all that the amplifying apparatus contains. The introduction of various sinusoïdal forces at the entrance could be replaced by a single short impulse at the input and a oscillographe at the output. The Heaviside operational calculus would allow one to determine all the coefficients of the equations defining apparatus. The problem of the ionized layer is of the same character and its constitution could be theoritically deduced from observations of complex signals resulting from an emitted impulse.

Le *Prof^r Wagner* ne croit pas bien comprendre M. van der Pol. Assurément on pourrait trouver un système susceptible de fournir les résultats obtenus, mais ce système ne serait pas unique il y aurait un nombre infini de systèmes différents qui seraient équivalents du point de vue considéré.

Dr. van der Pol answers that each of the two methods : *a*) sinuosoïdal forces and *b*) reponse to short impulse, could be used to predict the response of the amplifying set for any electromotive force applied to the entrance.

Prof^r Appleton asks for a list of members able to cooperate in the measurements of the height and ionisation of the upper atmosphere.

Les personnes qui pourront entrer en liaison à ce sujet sont : MM. APPLETON, DELLINGER, HATTORI (Radio-Committee, Academy House, Tokyo), LEJAY, LUGEON et WAGNER.

ANNEXES.

- I. *Comité National Français. — Étude de la Propagation.*
- II. *Contribution à l'Étude des lois de la Propagation des ondes hertziennes dans la gamme de 150 à 1 500 kc/s.* — R. Braillard.
- III. *Solar and Radio Relationships.* — L. W. Austin.

ANNEXE I.

Comité national français.

ÉTUDE DE LA PROPAGATION.

Le Comité National Français croit devoir attirer l'attention de l'Union Radio Scientifique Internationale sur l'intérêt qu'il y aurait à organiser d'une façon systématique des sondages réguliers de la haute atmosphère, c'est-à-dire des déterminations des couches réfléchissantes correspondant à une fréquence donnée.

De semblables études ont déjà été entreprises en Angleterre où on emploie la méthode indiquée par le Professeur Appleton, aux États-Unis (Bureau of Standards) et en France (Laboratoire National de Radioélectricité). Dans ces deux derniers pays, la méthode employée est celle dite de l'écho. Dans une note présentée à la réunion de la Commission IV de l'U. R. S. I. à Stockholm en 1930, le Comité National Français a attiré l'attention sur les avantages dus surtout à la simplicité que présente cette dernière méthode.

Il est évident d'autre part que le sondage de la haute atmosphère quel que soit le mode opératoire employé, ne peut conduire à des conséquences intéressantes que si on lui applique les règles qui président à l'organisation de toutes les recherches relatives à la Météorologie.

Il est nécessaire que toutes les mesures effectuées en divers points du globe soient centralisées et exécutées dans des conditions qui permettent de comparer les résultats obtenus.

Le Comité National Français propose donc la nomination d'une Sous-Commission composée de radio-électriciens, de physiciens et d'astronomes, laquelle aurait mission :

1° d'inviter les Comités Nationaux qui disposent des moyens d'action nécessaire à organiser dans leur pays de semblables sondages,

2° de donner son avis sur le mode opératoire qui lui semblerait préférable,

3° d'indiquer les longueurs d'onde approximatives sur lesquelles devraient être effectuées ces expériences,

4° de fixer les heures ou les moments de la journée où devraient être effectuées les mesures,

5° d'organiser la centralisation des résultats obtenus.

Il est absolument impossible de fixer d'une façon exacte les longueurs d'onde avec lesquelles devraient être effectuées ces mesures, elles doivent être déterminées par des conditions particulières (nature du poste dont le comité organisateur peut disposer, etc...)

Il conviendrait simplement de fixer la ou les bandes de fréquence dans lesquelles il paraît intéressant d'effectuer ces mesures par exemple : bande de 80 à 60 m., bande de 40 à 30 m., etc...

Le Comité National Français croit devoir indiquer que pour l'emploi de la méthode de l'écho, la bande de 80 à 60 m. lui semble la plus intéressante. D'après les recherches effectuées au Bureau of Standards, c'est celle pour laquelle les échos semblent le plus facilement observables. D'autre part, avec des ondes plus courtes, il est à redouter que le poste récepteur ne puisse percevoir l'onde directe, ce qui rendrait l'emploi de la méthode de l'écho illusoire.

Le Comité National Français et le Comité Américain ont organisé sous le nom d'Ursigrammes des messages radiotélégraphiques quotidiens donnant des renseignements sur divers points de la physique du globe. (Météorologie, Magnétisme, État du soleil).

Si des sondages journaliers de la couche d'Heaviside étaient effectués, cette donnée pourrait être ajoutée aux ursigrammes.

ANNEXE II.

CONTRIBUTION A L'ÉTUDE DES LOIS DE PROPAGATION DES ONDES HERTZIENNES DANS LA GAMME 150 A 1 500 kc/s (2 000 A 200 m).

Lors de sa réunion au Sommering, en février dernier, le Conseil de l'Union Internationale de Radiodiffusion, sur la proposition de sa Commission Technique, décida de mettre à la disposition de cette dernière les ressources de ses membres, en personnel technique et en matériel, en vue d'entreprendre sur une large échelle, des mesures systématiques de la valeur du rayon indirect des stations de radiodiffusion.

Les buts de cette expérience étaient les suivants :

a) Apporter une contribution utile à l'étude des phénomènes de propagation des ondes hertziennes,

b) Tenter de déterminer le *rayon d'action nuisible* des stations de radiodiffusion, c'est-à-dire la limite à partir de laquelle le rayon indirect, ou onde d'espace, cesse de provoquer des interférences nuisibles dans le *rayon d'action utile* des stations travaillant sur des fréquences voisines, lequel est limité en fait au rayon d'action de l'onde de surface,

c) Déterminer si possible l'effet de la longueur d'onde d'émission, de la situation orographique et géographique de la station, de la direction du rayonnement par rapport au méridien, de la forme de l'antenne d'émission, etc...

d) éventuellement, tirer des résultats pratiques de l'expérience, et étudier les modifications à apporter dans la répartition actuelle des longueurs d'onde entre les stations de radiodiffusion, en vue d'atténuer les interférences spécialement ressenties pendant la période d'hiver, par suite de l'encombrement considérable de la bande de fréquence allouée à la radiodiffusion.

L'essai ayant été poursuivi avec succès, mes collègues et moi avons estimé qu'il était opportun de profiter des réunions de Copenhague pour en porter les premiers résultats globaux à la connaissance des experts réunis ici.

J'insisterai toutefois sur le fait qu'il ne s'agit que d'une première analyse de l'ensemble des mesures effectuées, le temps ayant manqué pour poursuivre l'examen de la question sous tous ses aspects accessibles.

Programme des essais.

1. Les mesures ont été effectuées chaque soir (dimanche excepté) du 3 mars au 7 avril, entre 18 heures et 24 heures, T. M. G. sans interruption.

2. Pendant chaque séance, on observa deux stations seulement, en alternant d'heure en heure, ce qui correspondait à 3 heures d'observation pour chaque station, réparties sur une durée globale de 5 heures.

3. On observa 32 stations de radiodiffusion, reconnues pour leur stabilité, réparties en des points très divers de l'Europe, et couvrant pratiquement toute la gamme à observer (sauf entre 1.000 et 545 kilo-cycles).

4. Les mesures furent effectuées dans 11 centres différents, situés à Helsinki, Stockholm, Oslo, Kobenhavn, Tatsfield (près de London), Eindhoven, Berlin, Praha, Wien, Buda-Pest, Torino.

Chacun de ces centres est pourvu d'un appareil moderne pour la mesure du champ, et la plupart d'entr'eux étaient équipés de façon à procéder à un enregistrement continu des variations de champ, avec une vitesse de déroulement de la bande de un centimètre par minute.

5. Toutes les caractéristiques d'émission des stations émettrices (puissance, forme de l'antenne, etc...) et toutes les mesures, (y compris les diagrammes d'enregistrement) furent centralisés au Laboratoire de Contrôle de l'U. I. R. à Bruxelles, où l'on procéda à leur dépouillement.

Cette opération n'est pas complètement terminée, (il a été rassemblé près de 1.500 mètres de bandes enregistrées), mais le classement des premiers résultats obtenus semble déjà très instructif.

Je me permettrai de les exposer sommairement, en espérant qu'ils constitueront des matériaux utiles aux physiciens qui étudient le mécanisme de la couche de Kennelly-Heaviside et aux ingénieurs des radiocommunications qui doivent tenir compte de ses effets.

Méthode de classement.

Les stations émettrices étant, en général, de puissances différentes, j'ai ramené pour chacune d'elles la valeur du champ mesuré à une puissance de 1 kilowatt radié.

Il y a quelque incertitude dans la détermination exacte de la puissance réellement radiée par chaque station, mais les erreurs qui peuvent en résulter n'affectent que très peu la valeur réelle du champ mesuré et n'influencent pas l'allure générale des phénomènes observés.

Pour chaque station, j'ai noté, pour chaque centre d'observation, la valeur maximum du champ enregistré, ce qui a permis de tracer une courbe des maxima maximorum du champ en fonction de la distance, pour une station donnée.

Quelques-unes de ces courbes sont reproduites en annexe (¹). Il y figure également :

a) Une courbe d'atténuation théorique, en fonction de l'inverse de la distance, en supposant qu'il n'y a pas d'atténuation. L'effet de courbure de la terre a été négligé, pour les distances considérées;

b) Une courbe d'atténuation théorique, correspondant, pour la fréquence envisagée, à une conductibilité du sol égale à 10^{-13}CGS, valeur moyenne. Cette courbe, établie d'après les théories d'Austin, Cohen, Sommerfeld, Watson, van der Pol, etc... correspond sensiblement à la réalité, suivant les mesures effectuées par P. P. Eckersley et de nombreux autres expérimentateurs. Cette courbe indique la valeur du rayon direct ou onde de surface.

D'une manière générale, on peut remarquer que les mesures effectuées dans les divers centres sont très cohérentes et même fréquemment très concordantes.

Pour chaque mesure, j'ai fait figurer également la direction de propagation vers le centre d'observation par rapport au méridien.

L'examen de l'ensemble des résultats a permis de déduire certaines courbes moyennes, lesquelles, avec une approximation suffisante, permettent de préciser, en valeur absolue, des phénomènes assez mal définis, à ma connaissance, jusqu'à ce jour.

Les graphiques ci-joints s'expliquent par eux-mêmes. J'en entreprendrai toutefois une analyse succinte.

Effet de la fréquence.

Le rayon indirect prend une importance de plus en plus grande au fur et à mesure que la fréquence augmente, ce qui est bien connu.

A la fréquence de 160 kc/s., sa valeur maximum, suit très exactement la courbe d'atténuation correspondant, pour l'onde de surface, à une conductibilité du sol égale à 10^{-13}CGS.

Mais pour des fréquences très légèrement supérieures, l'effet du rayon réfléchi commence à se faire sentir, pour atteindre son maximum aux fréquences les plus élevées.

Cette valeur maximum atteint et dépasse 1 millivolt par mètre pour 1 kilowatt radié, ce qui représente plus de dix fois les valeurs admises il y a deux ans, et explique la sévérité des interférences constatées parfois durant les longues nuits d'hiver, même à proximité des stations d'émission, du fait de stations relativement très éloignées.

Si l'on admet qu'en raison du « fading », le seul rayon d' « action agréable » des stations soit celui qui correspond au champ d'action de l'onde de surface, la supériorité des ondes longues, en

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(¹) Page 43.

matière de radiodiffusion, apparaît immédiatement.

Effet de la distance.

D'une manière générale, on constate que le maximum du rayon indirect se manifeste à des distances de l'ordre de 600 kilomètres.

La zone de « quasi-silence », située à courte distance des émetteurs, se manifeste à partir des fréquences de l'ordre de 600 kc/s. et s'aggrave de plus en plus quand la fréquence augmente.

A 1.200 km., les fréquences de 400 à 1.500 kc/s. donnent des valeurs maxima du rayon indirect sensiblement équivalentes.

Vers 2.000 km., le maximum est observé par les fréquences de l'ordre de 600 kc/s.

Remarque.

Ainsi que l'U. I. R. l'a déjà signalé dans sa réponse à la question 11 du C. C. I. R., la valeur maximum du rayon indirect, à des distances comprises entre 300 et 1.600 km., est parfois très notablement supérieure à la valeur du rayon direct calculé en supposant qu'il n'y a pas d'atténuation.

Ceci confirme l'hypothèse qu'en un point donné, les rayons peuvent aboutir simultanément, en composant leurs effets, par plusieurs voies différentes correspondant à plusieurs aspects de la couche réfléchissante.

Les valeurs mesurées atteignent 5 fois les valeurs calculées d'après la loi de la distance inverse sans atténuation, et en fait un chiffre

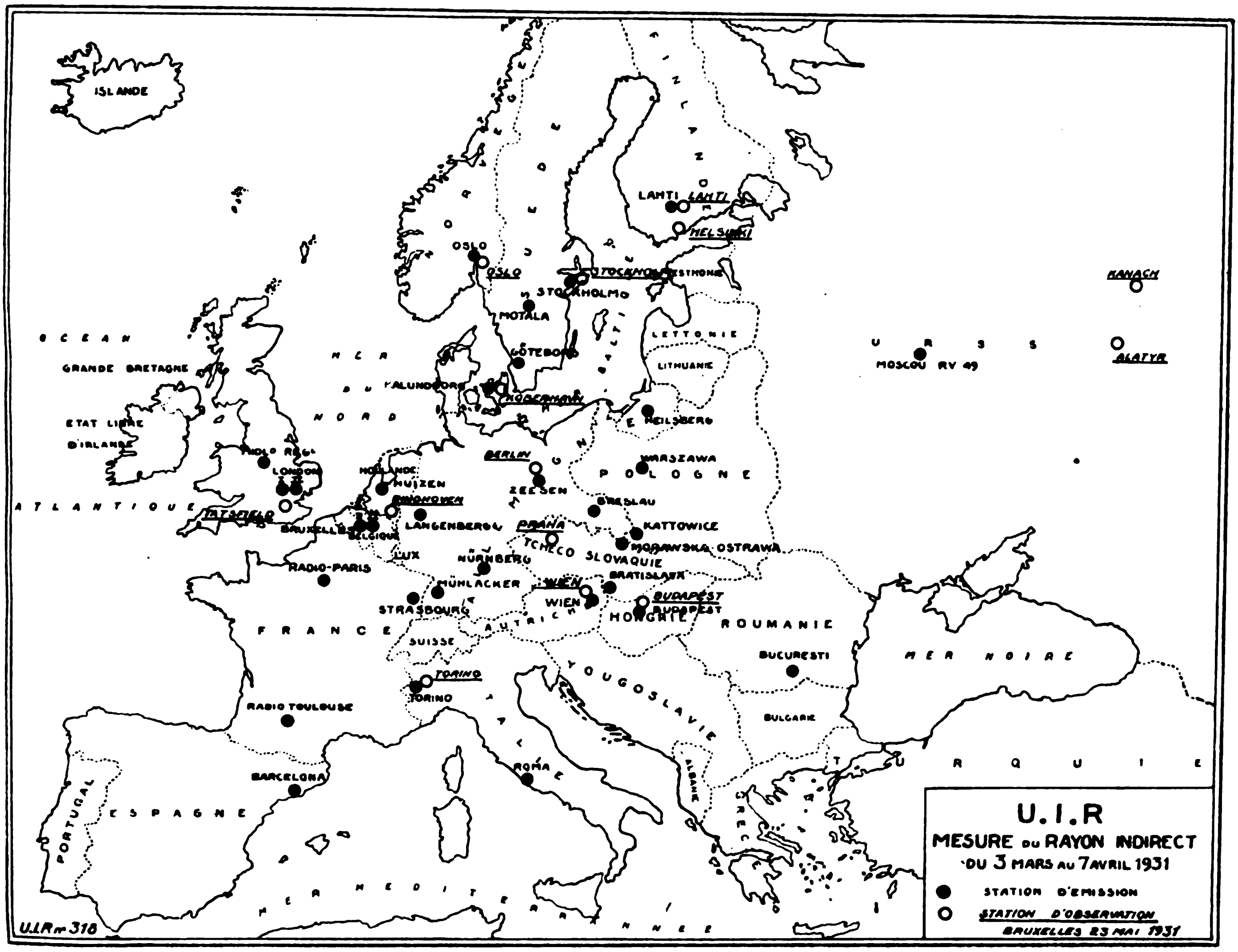


FIG 1

supérieur si l'on tient compte de tous les éléments du problème.

Ampleur du fading.

Sur quelques courbes individuelles des stations nous avons fait figurer des minima minimorum des valeurs de champ observées.

Ceci n'a pu être fait (question d'échelle) que pour les ondes les plus longues.

Ayant analysé par ailleurs les écarts maxima entre les valeurs du champ mesuré pendant des périodes d'une heure, il a été constaté de grandes différences suivant les fréquences d'émission, ce qui est bien connu d'une façon générale.

Toutefois, il a été constaté que l'ampleur du fading croissait très rapidement à partir de 150 kc/s. suivant la loi ci-après :

Fréquence.	Rapports des champs extrêmes.	Ecarts en décibels.
160 kc/s.	4	12
180	10	20
200	20	26
300	80	38
600	300	50
1.000	360	52
1.250	200 (?)	46 (?)

Les valeurs indiquées peuvent être considérées comme des minima.

Les observations manquent pour les fréquences les plus élevées, et il n'est pas possible d'en déduire l'allure extrapolée du phénomène.

Par ailleurs, on constate, en règle générale, que l'ampleur maximum du fading se manifeste aux distances correspondant à l'apparition des valeurs maxima du rayon indirect.

Cadence du fading.

L'analyse systématique de ce phénomène n'a pas été effectué.

Toutefois, la cadence du fading s'accélère beaucoup quand la fréquence augmente, et l'on a observé, pendant de longues périodes (30 à 40 minutes) un fading régulier et prononcé à la cadence de 8 à 10 secondes, pour des fréquences de l'ordre de 1.200 kc/s.

Effet de la direction.

Contrairement à notre attente, il n'a pas été observé, lorsque la nuit est complète sur tout le parcours du rayon, d'effet de direction par rapport au méridien.

Effet de l'antenne.

Cet effet se manifeste, d'une part, en fonction de l'effet directif de l'antenne dans le plan horizontal, d'autre part, en fonction du diagramme de rayonnement dans le plan vertical (caractéristiques électriques).

L'analyse complète n'a pas été effectuée, mais l'effet de certains types d'antenne bien connus pour favoriser l'action distance a été observé.

Conclusion.

En résumé l'expérience entreprise par l'U. I. R. a donné d'emblée des résultats riches en enseignements, permettant d'effectuer un premier classement quantitatif des phénomènes assez mal définis jusqu'ici, et d'en tirer des conclusions pratiques.

Loin de moi l'idée de vouloir en dégager des lois scientifiques rigides : dans un tel domaine, il convient d'être prudent et de répéter sans relâche, dans des circonstances de temps et de lieu les plus variées, les mêmes expériences.

L'U. I. R. n'y faillira pas et de nouveaux essais seront entrepris prochainement, sur la base d'une collaboration internationale agréable et féconde.

R. Braillard.

Président de la Commission Technique et Directeur du Laboratoire de Contrôle de l'Union Internationale de Radiodiffusion (U. I. R.)

Bruxelles, le 24 mai 1931.

Amplitude maximum du **Fading**, *mesuré au cours de séances de 1 heure, en fonction de la fréquence.*

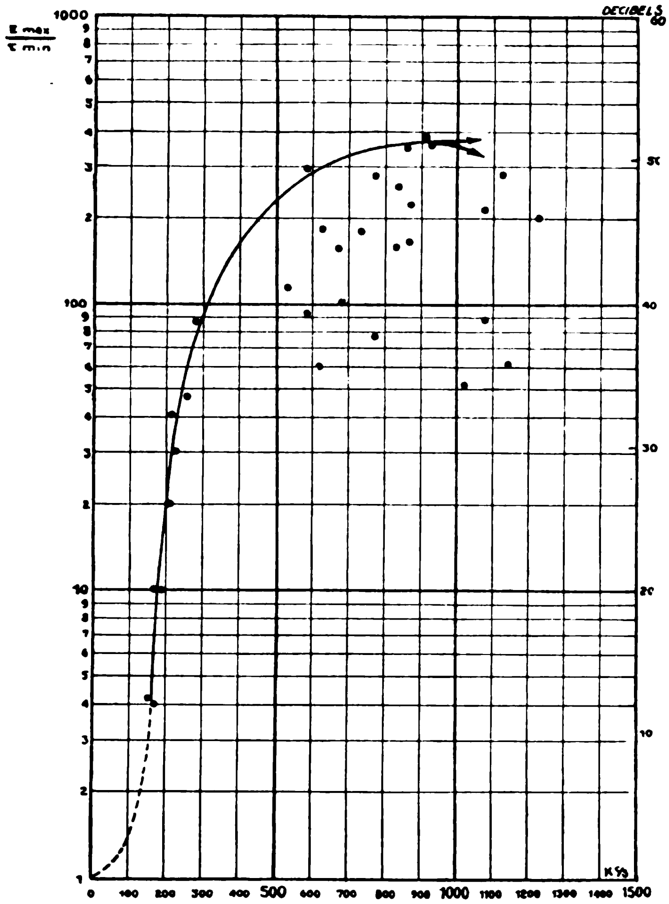


FIG. 2.

Moyenne des maxima du rayon indirect. Distance constante, fréquence variable, puissance 1 Kw radié.

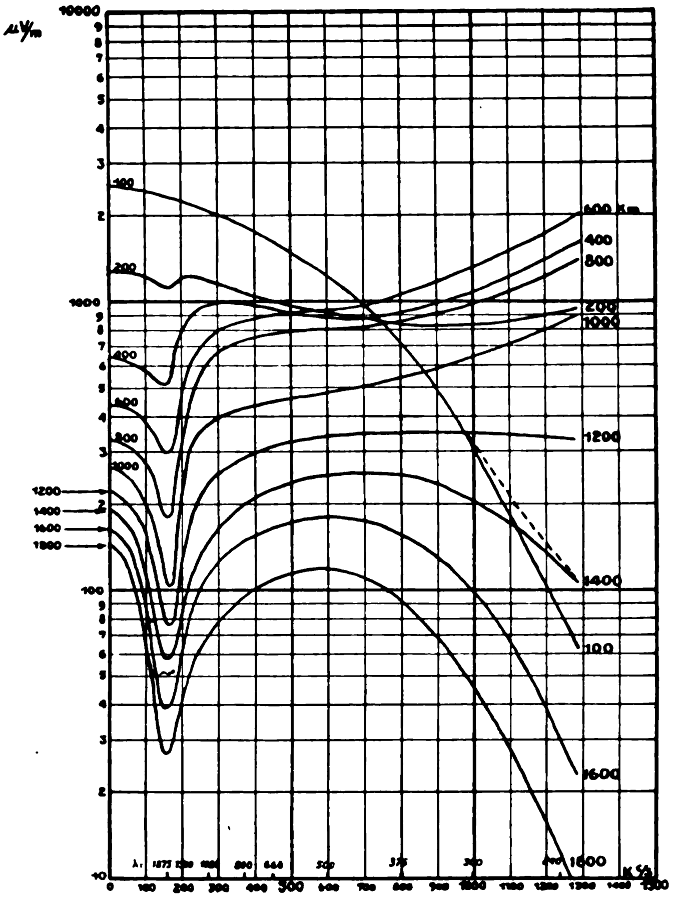


FIG. 3.

Moyenne des maxima du rayon indirect. Fréqence constante, distance variable, puissance 1 Kw radié.

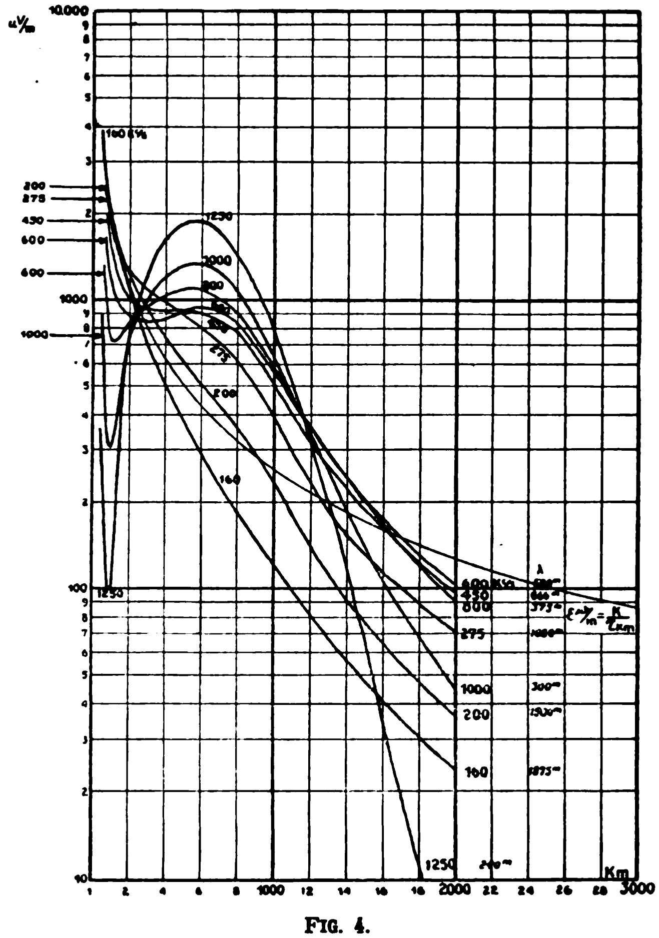


FIG. 4.

Valeur maximum du rayon indirect en fonction de la distance et de la fréquence ramenée à 1 Kw rayonné.

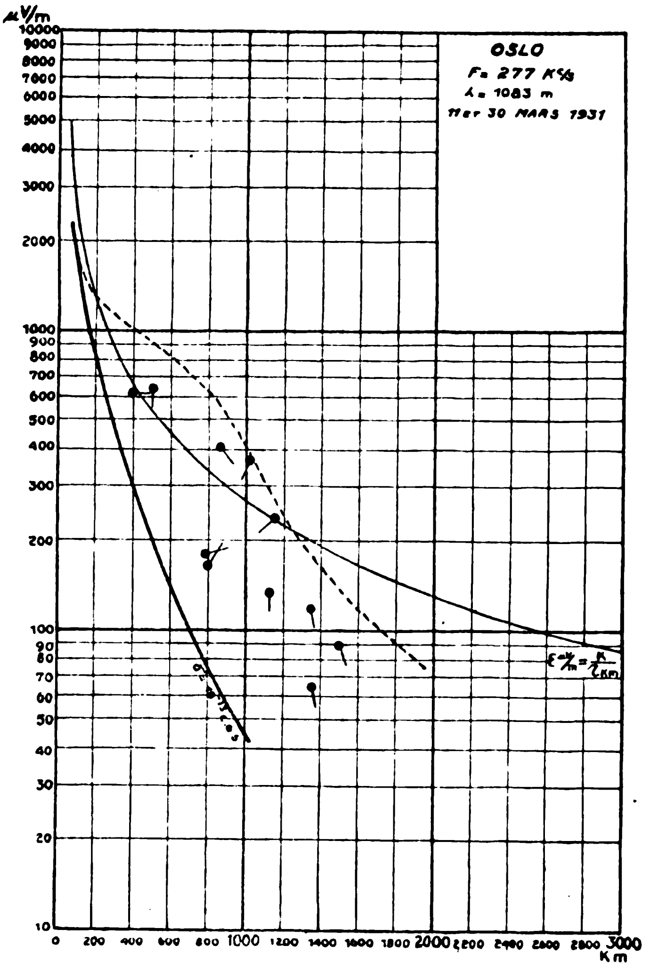


FIG. 5.

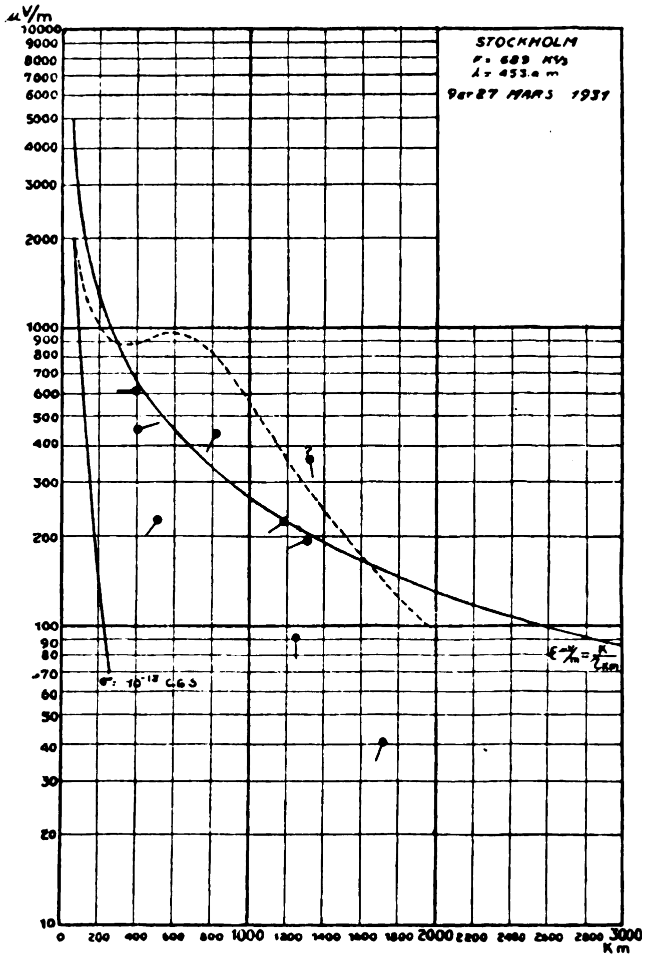


FIG. 6.

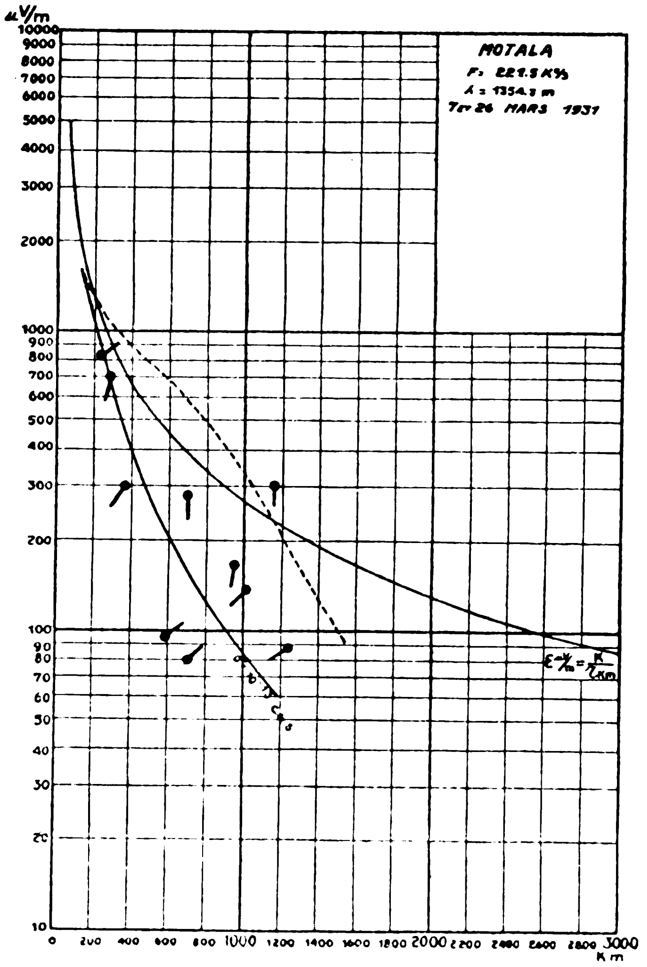


FIG. 7.

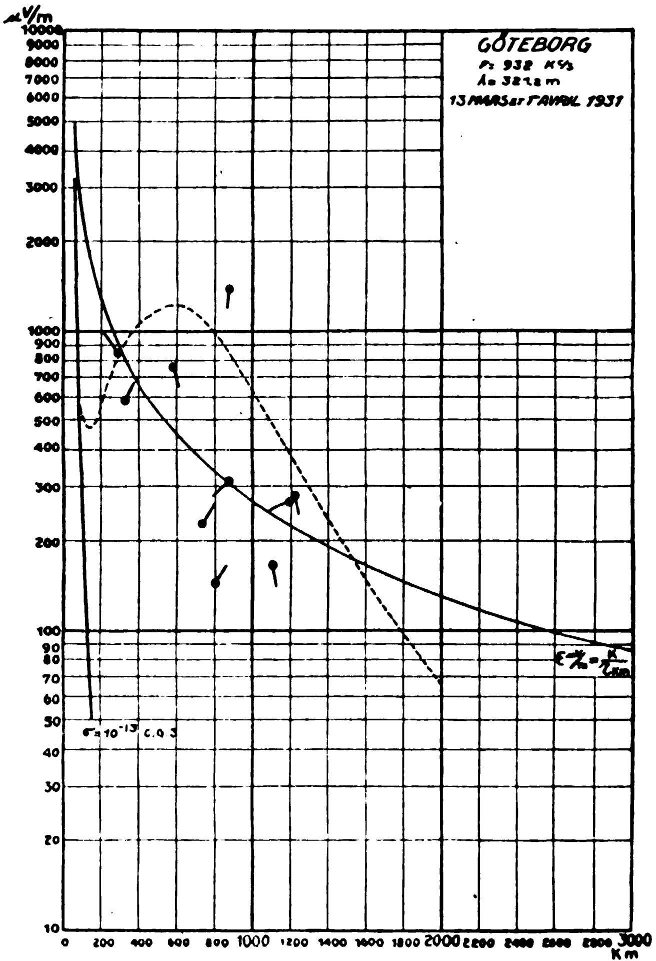


FIG. 8.

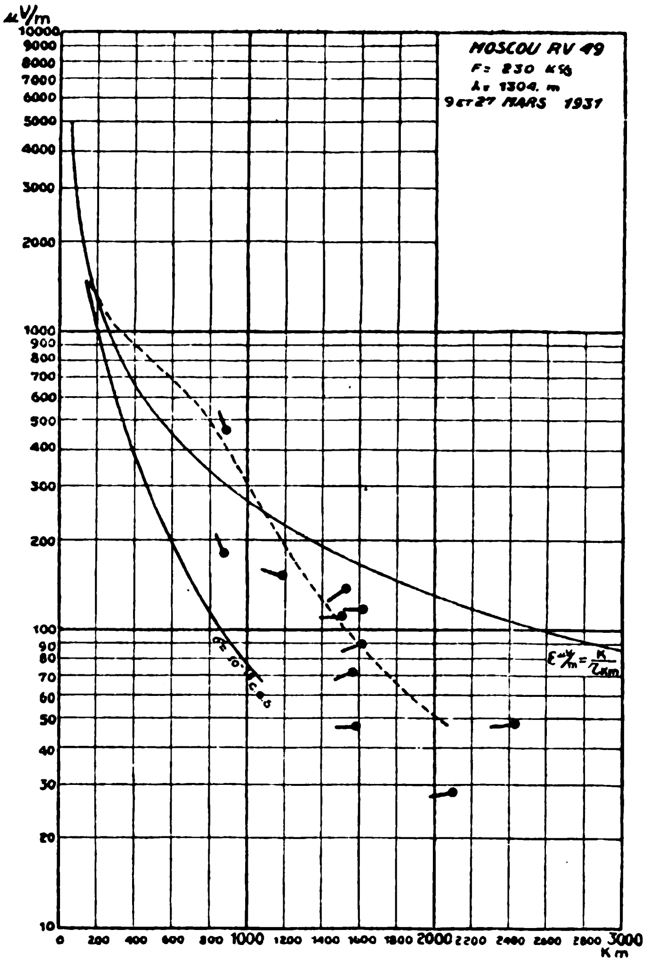


FIG. 9.

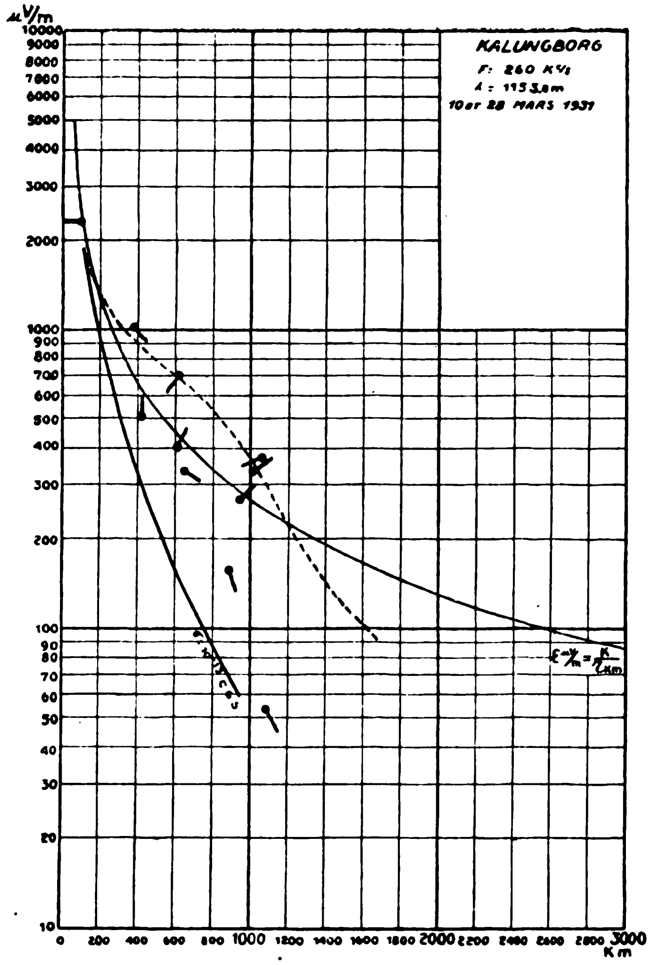


FIG. 10.

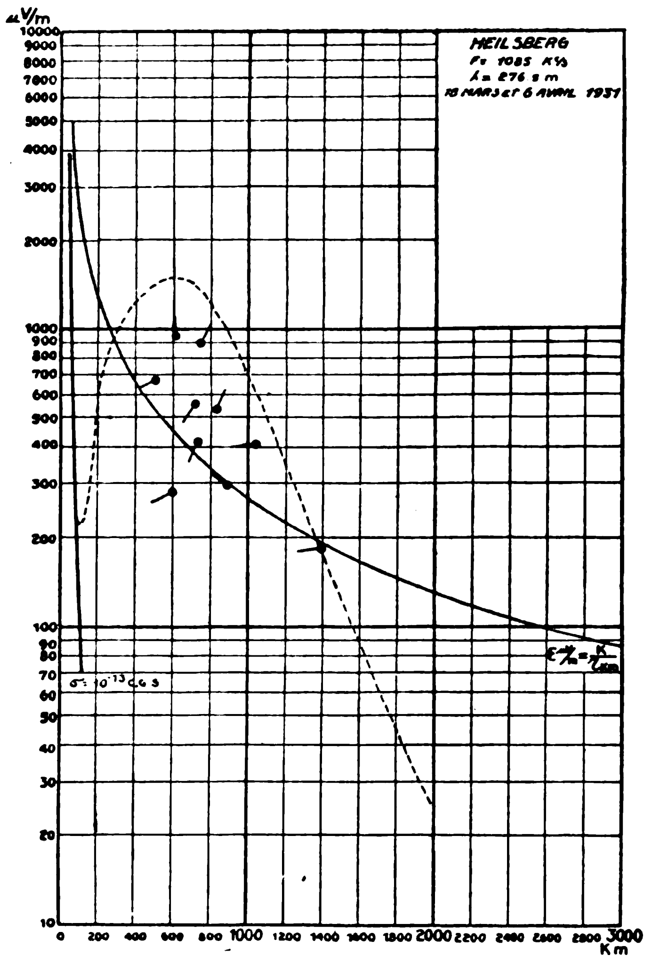


FIG. 11.

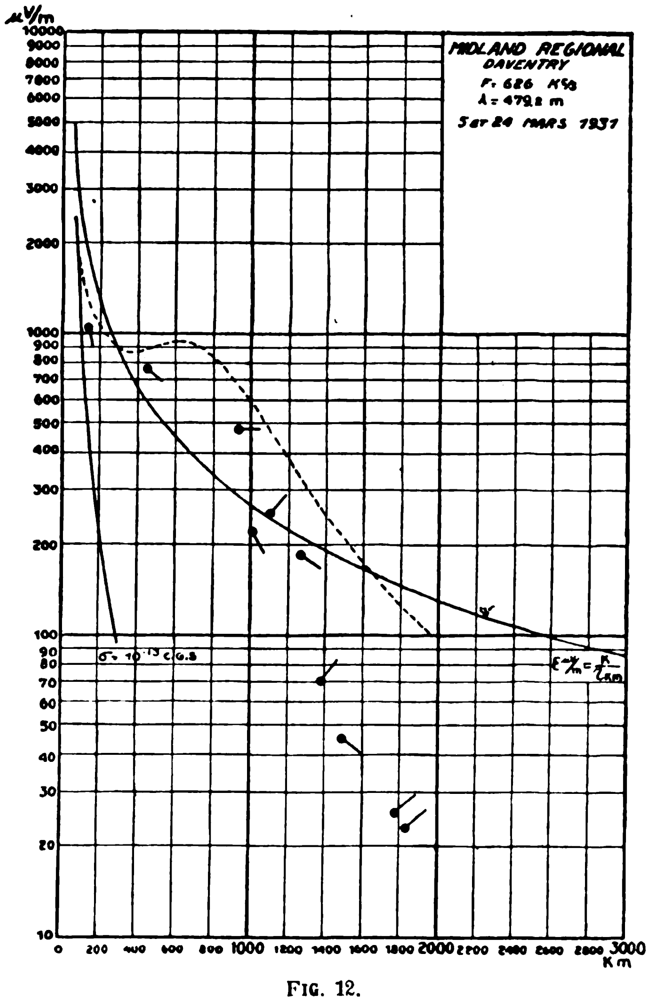


FIG. 12.

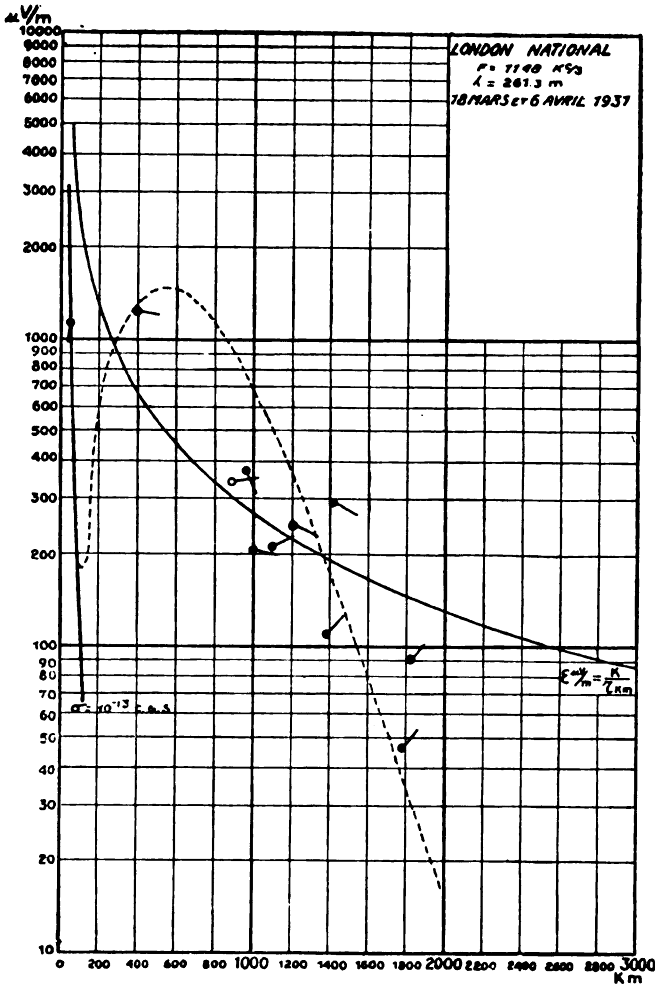


FIG. 13.

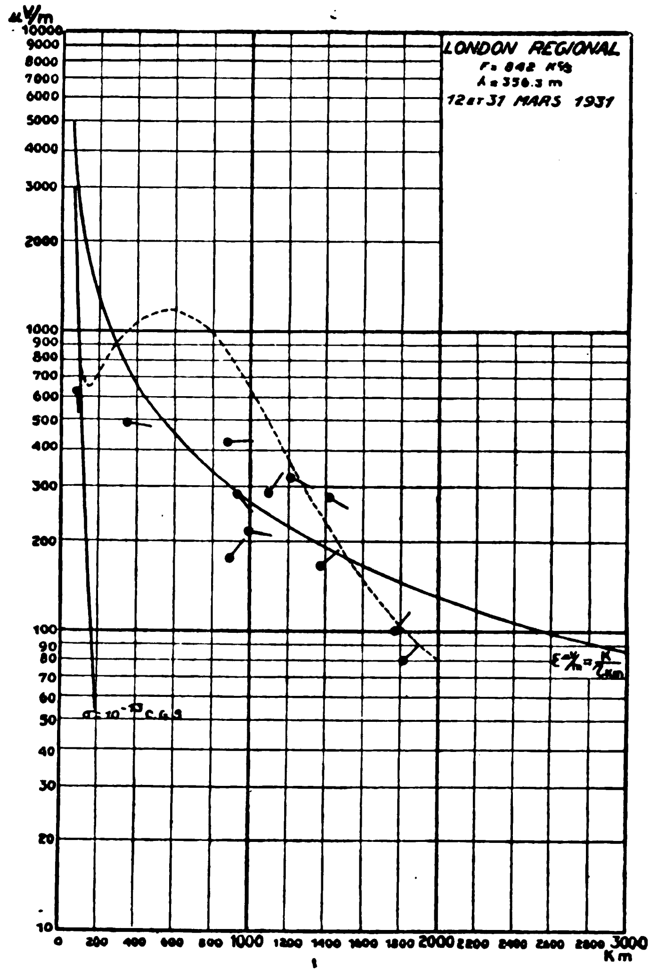


FIG. 14.

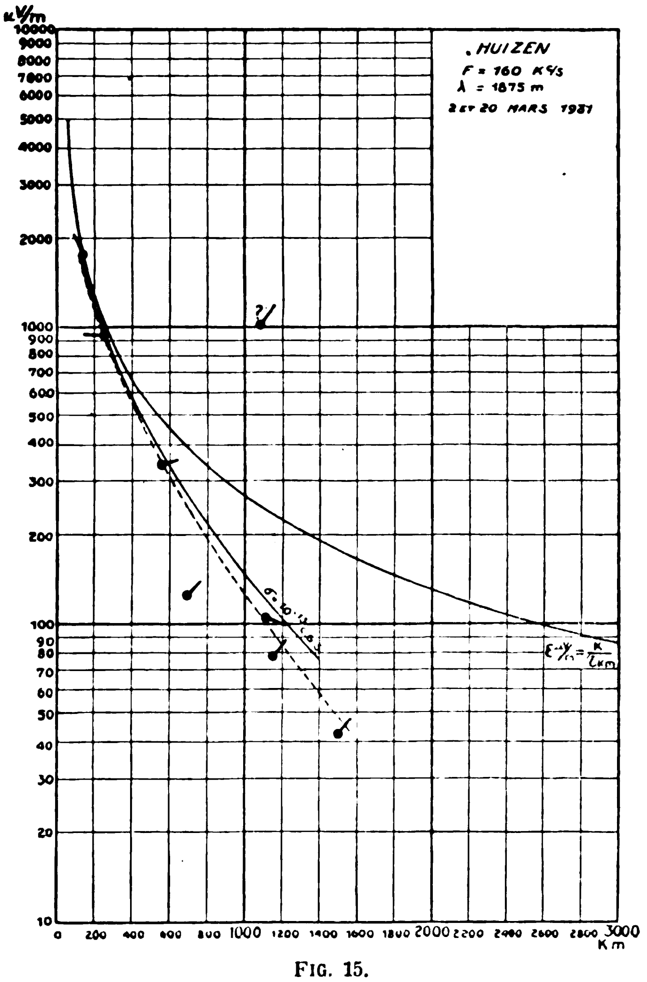


FIG. 15.

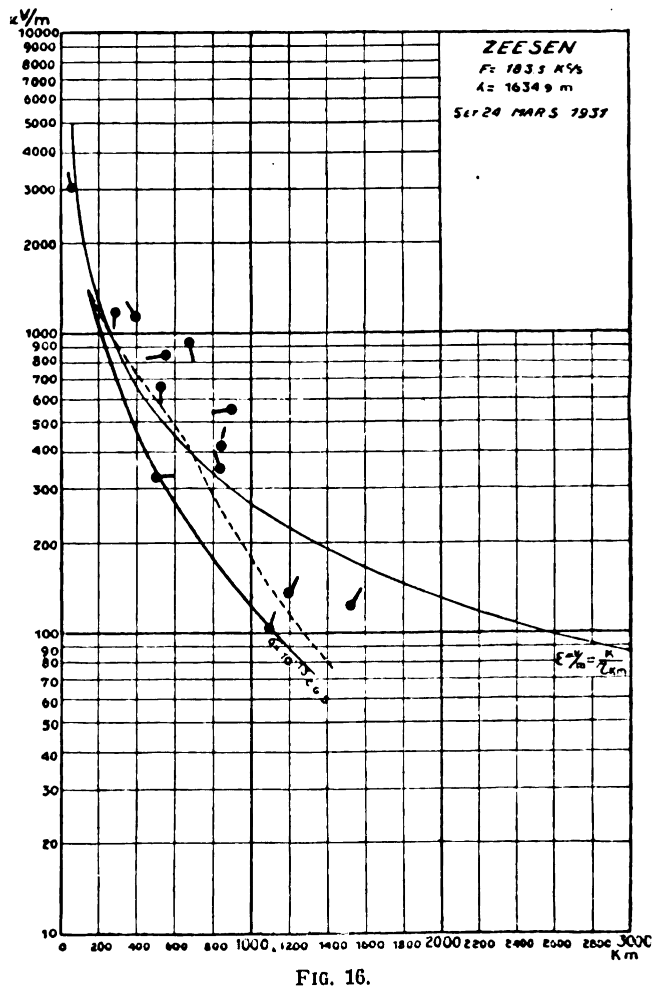


FIG. 16.

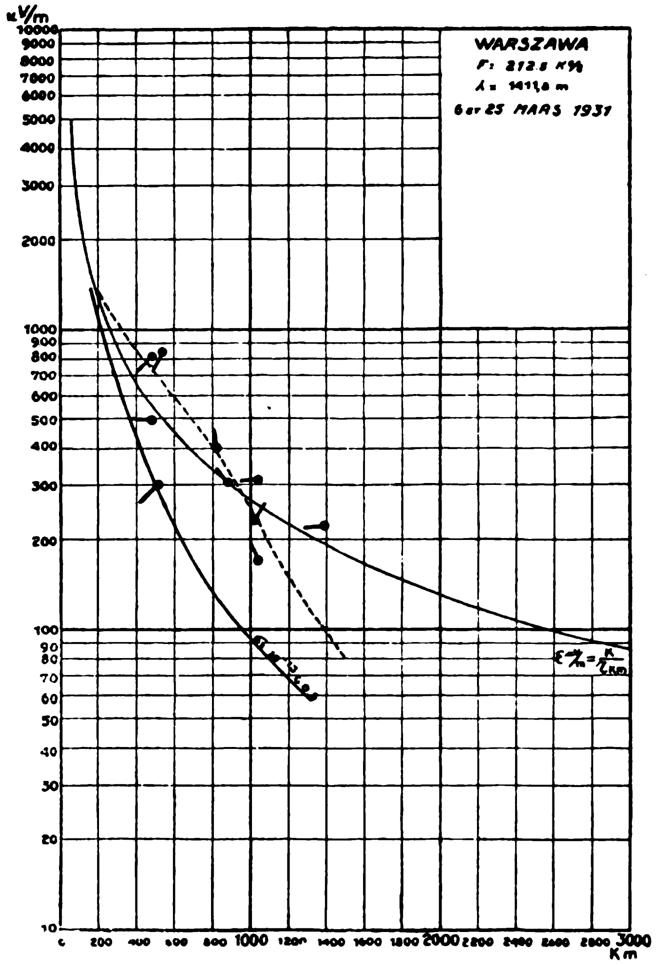


FIG. 17.

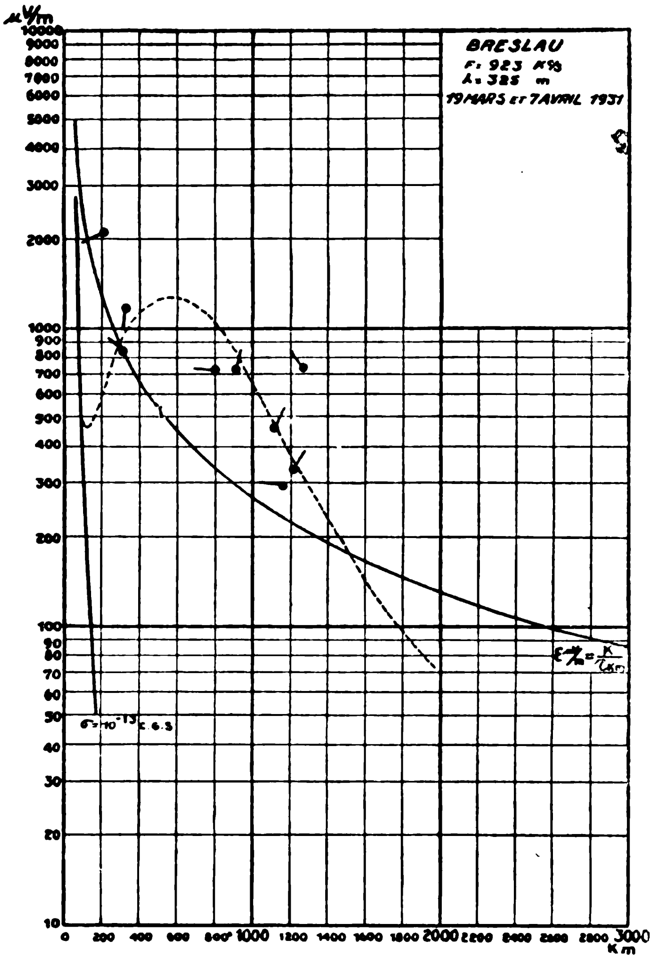
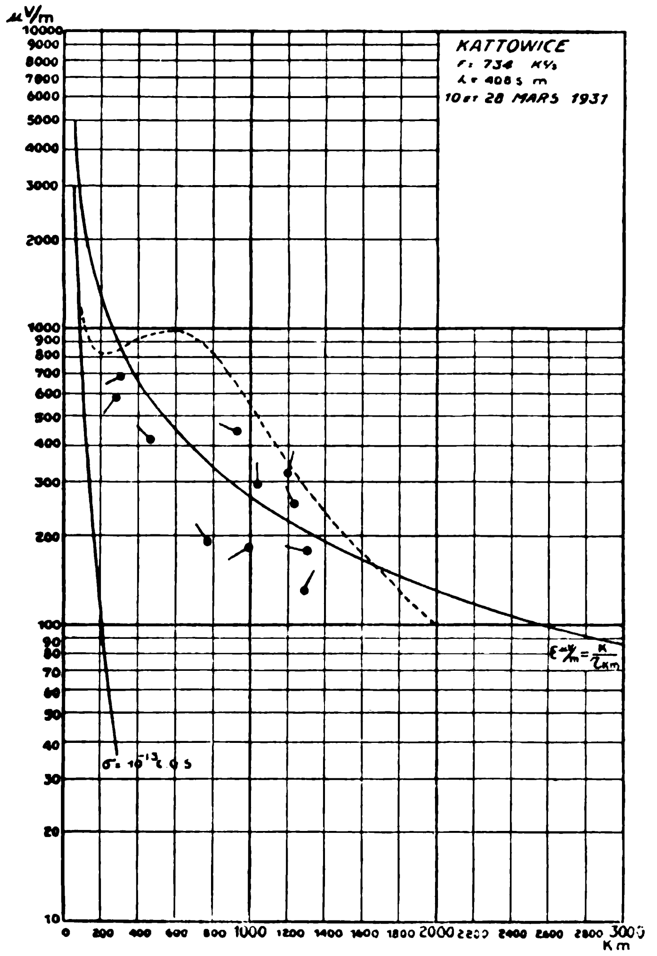


FIG. 18.



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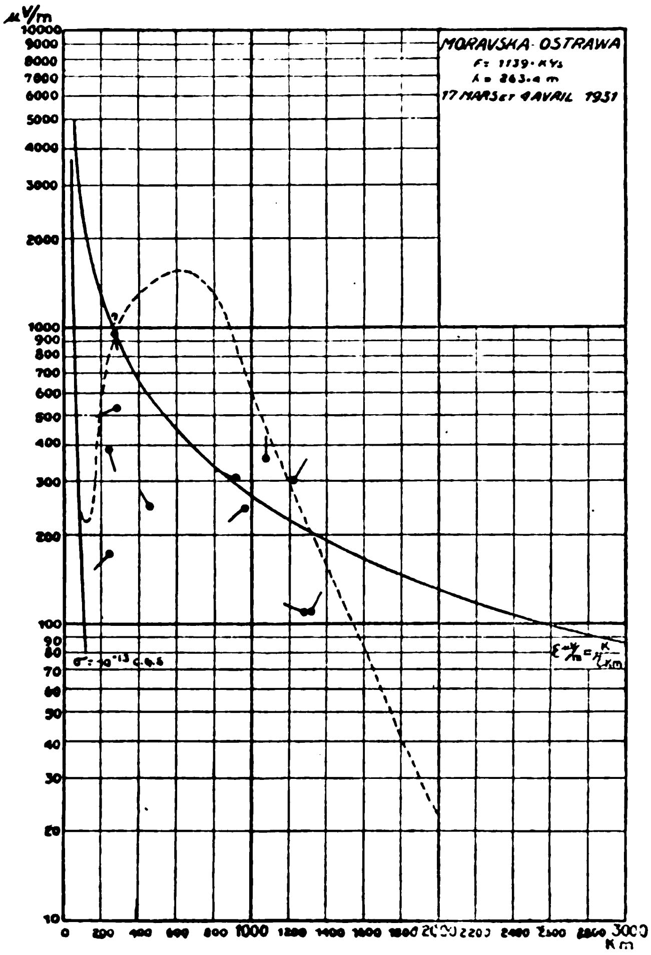


FIG. 20.

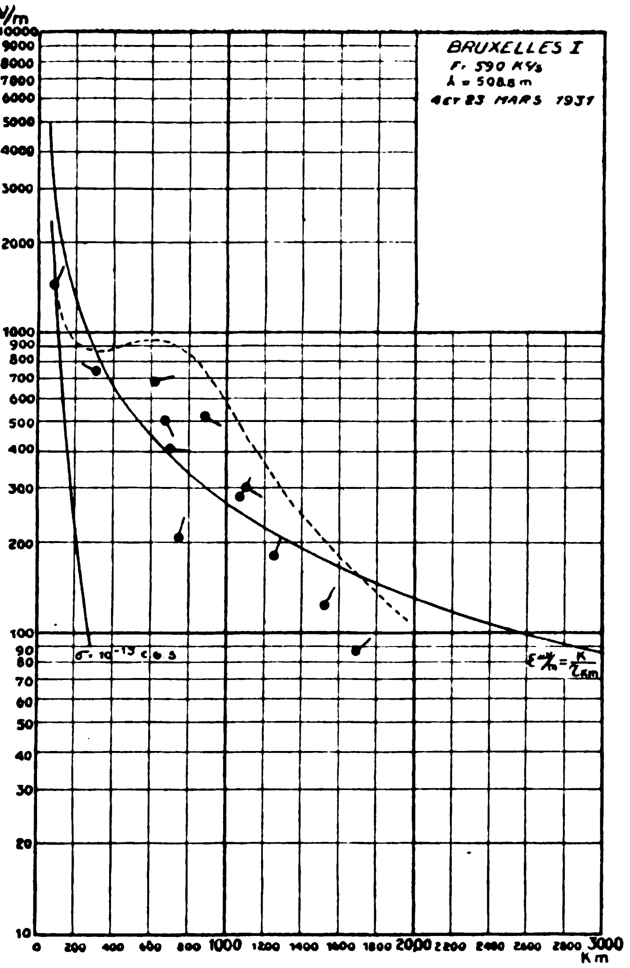
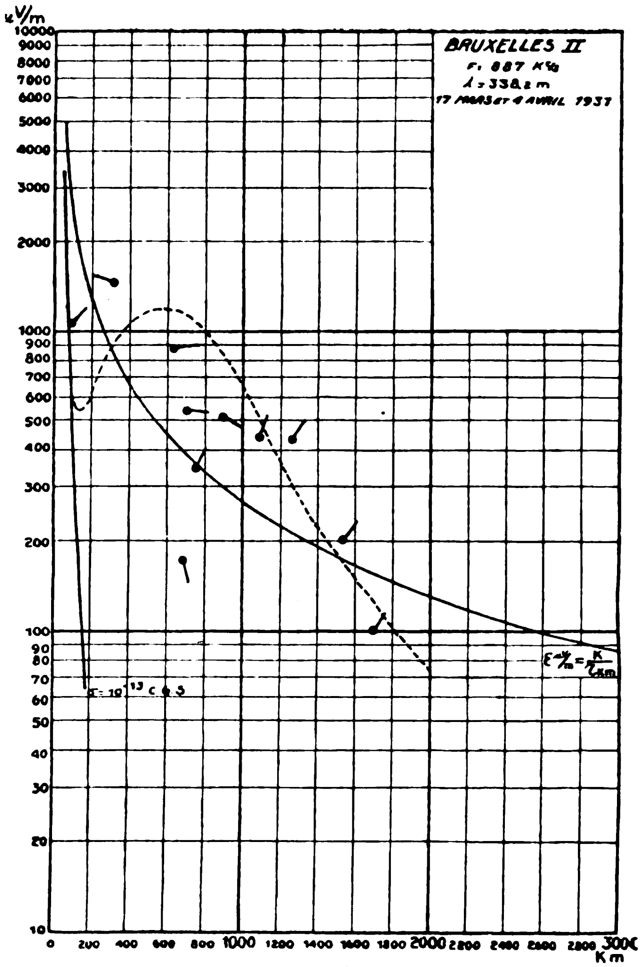


FIG. 21.



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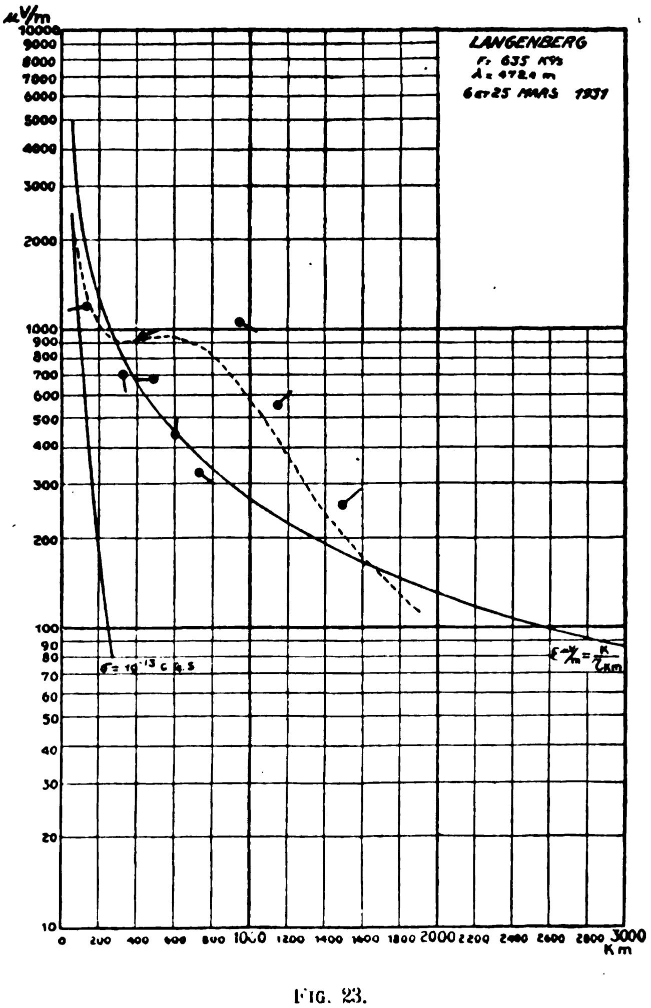

FIG. 23.

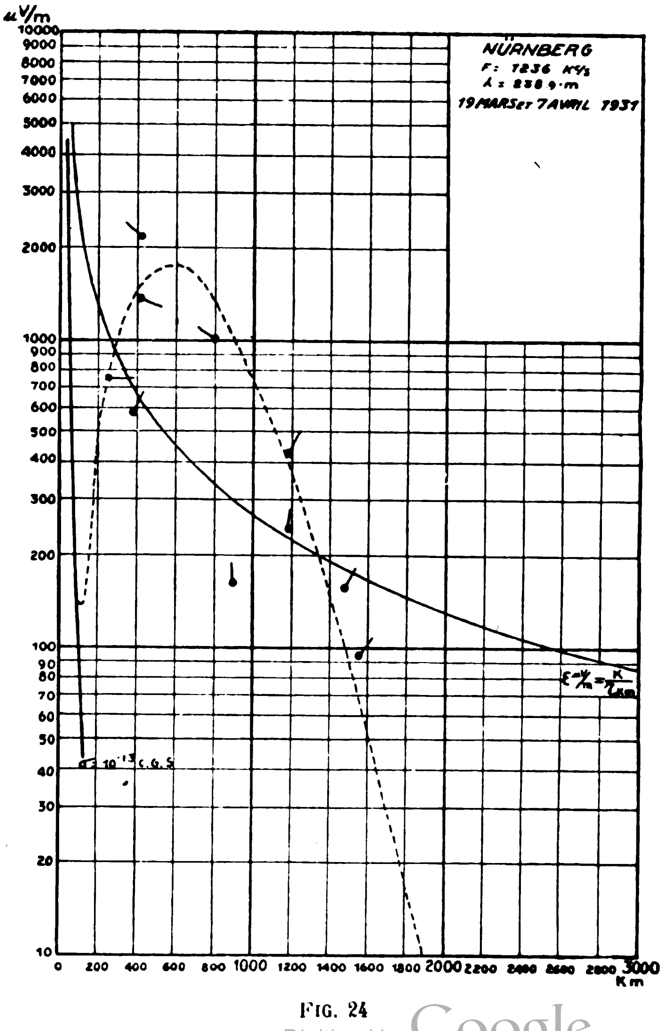

FIG. 24

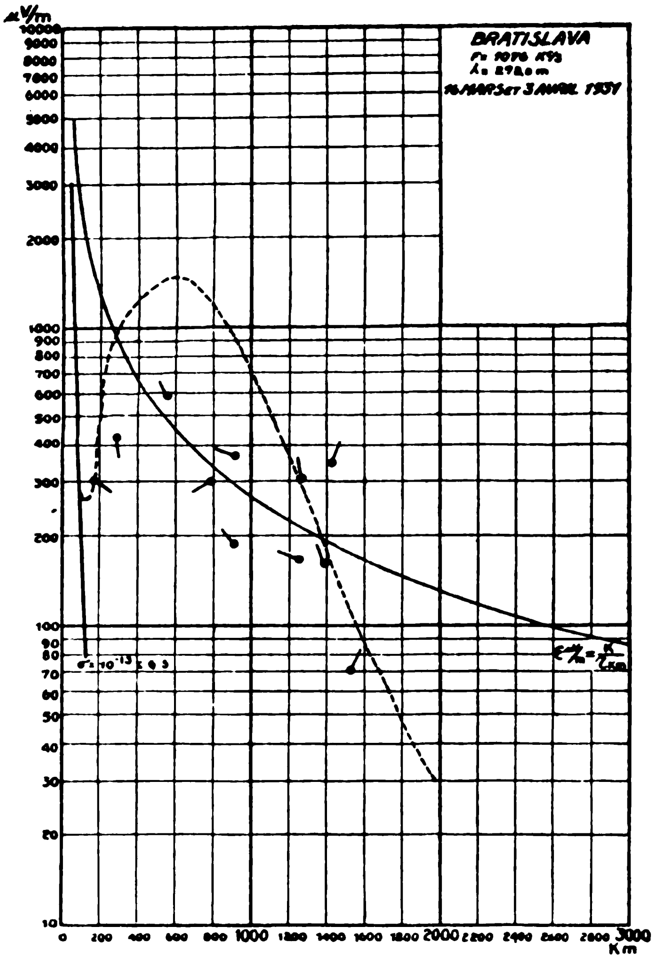

FIG. 25.

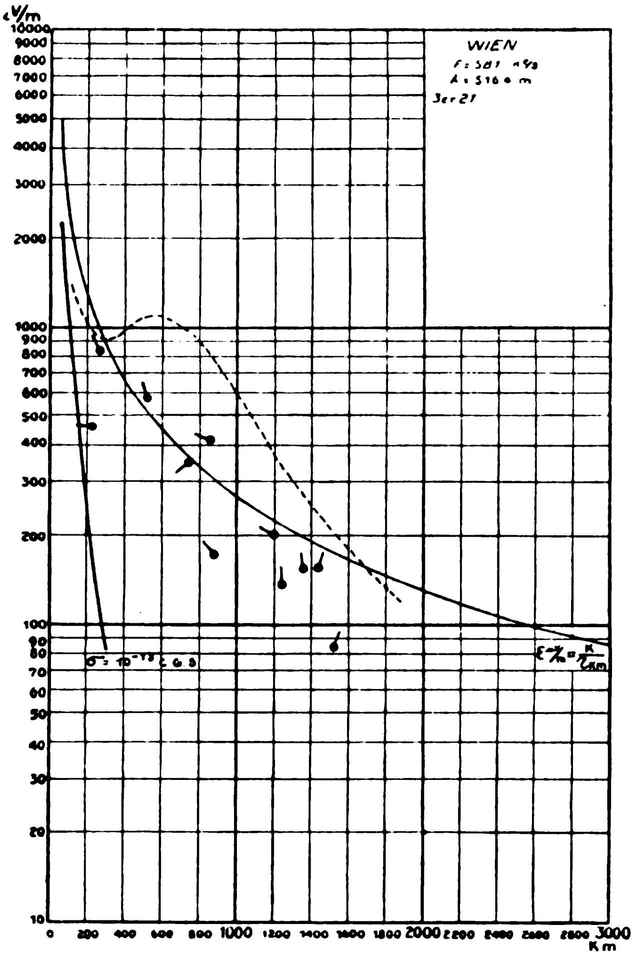

FIG. 26.

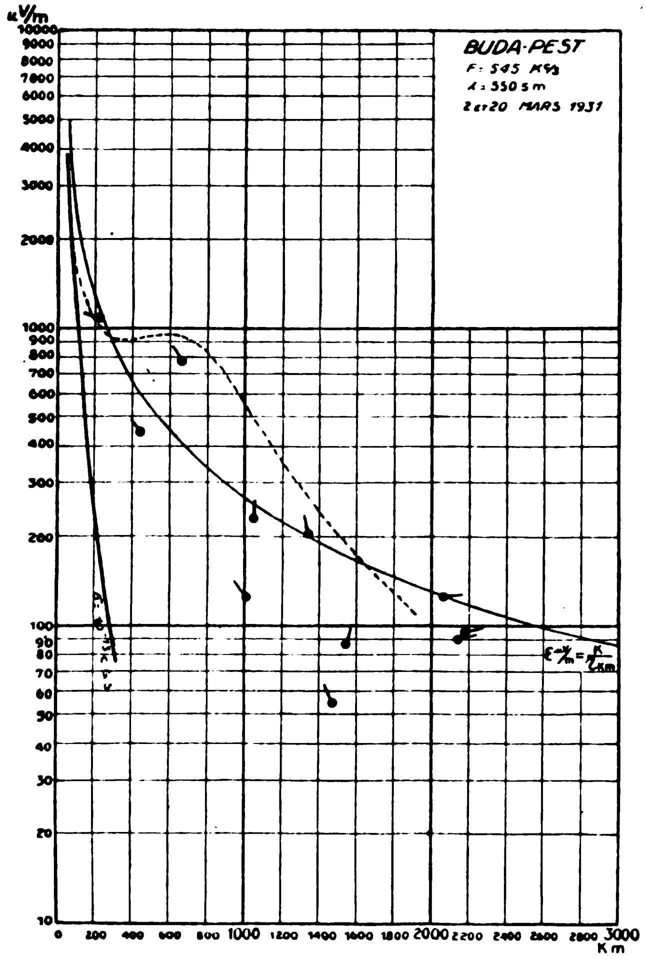

FIG. 27.

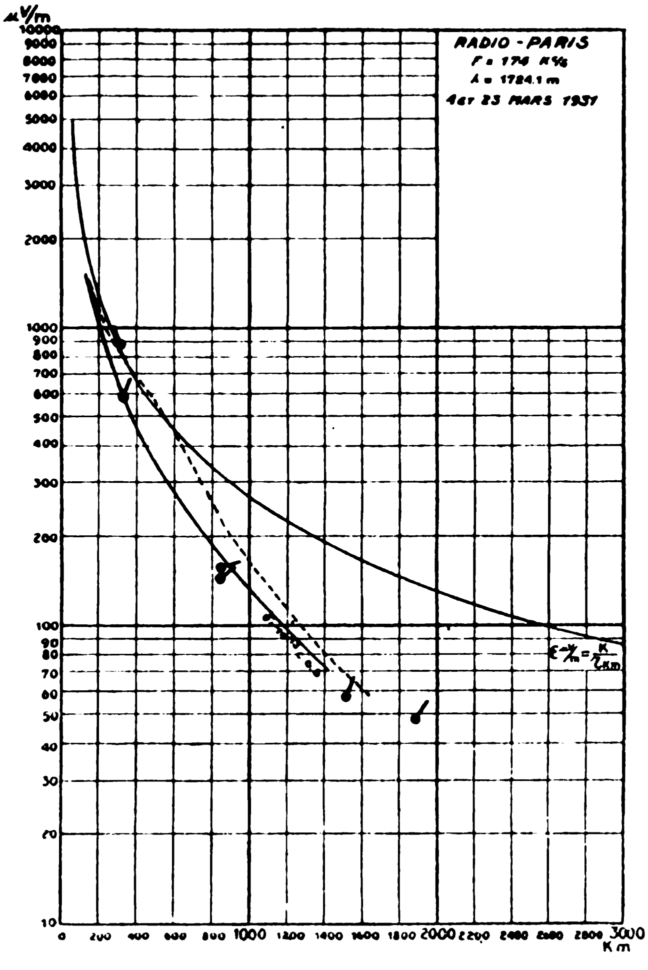

FIG. 28

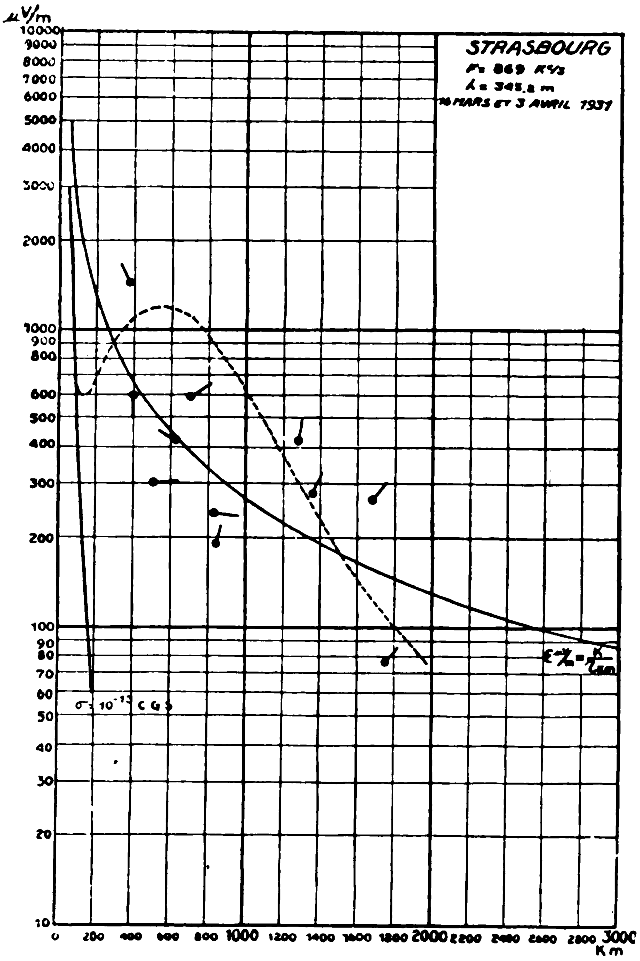

FIG. 29.

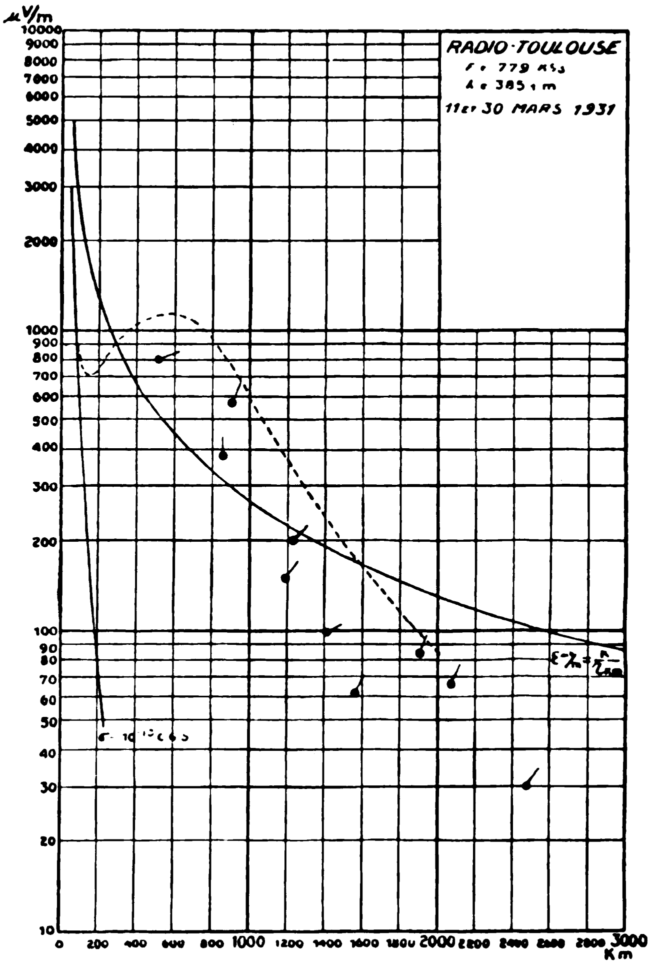

FIG. 30.

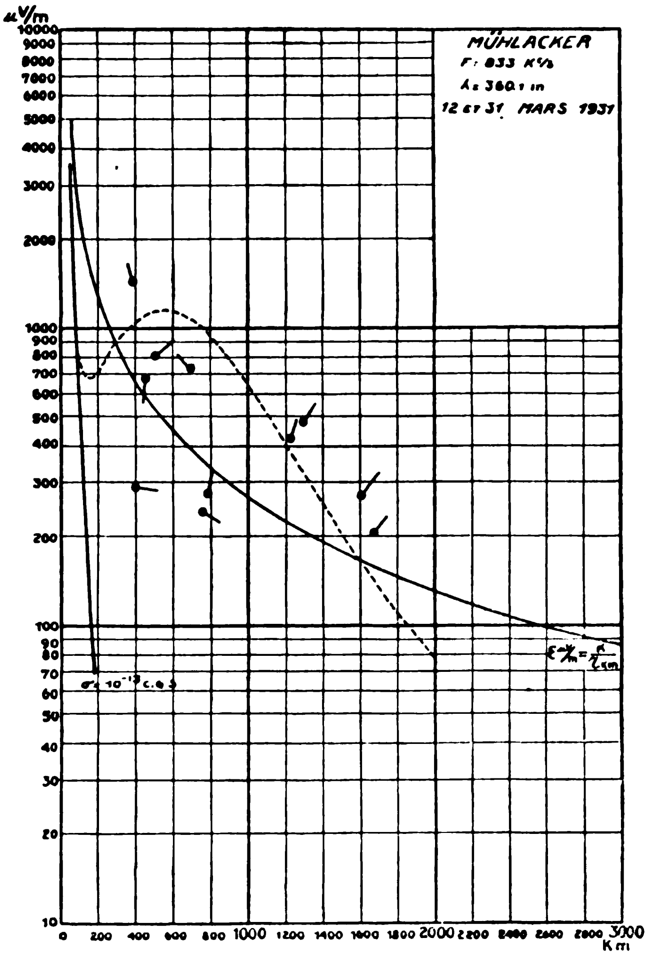

FIG. 31.

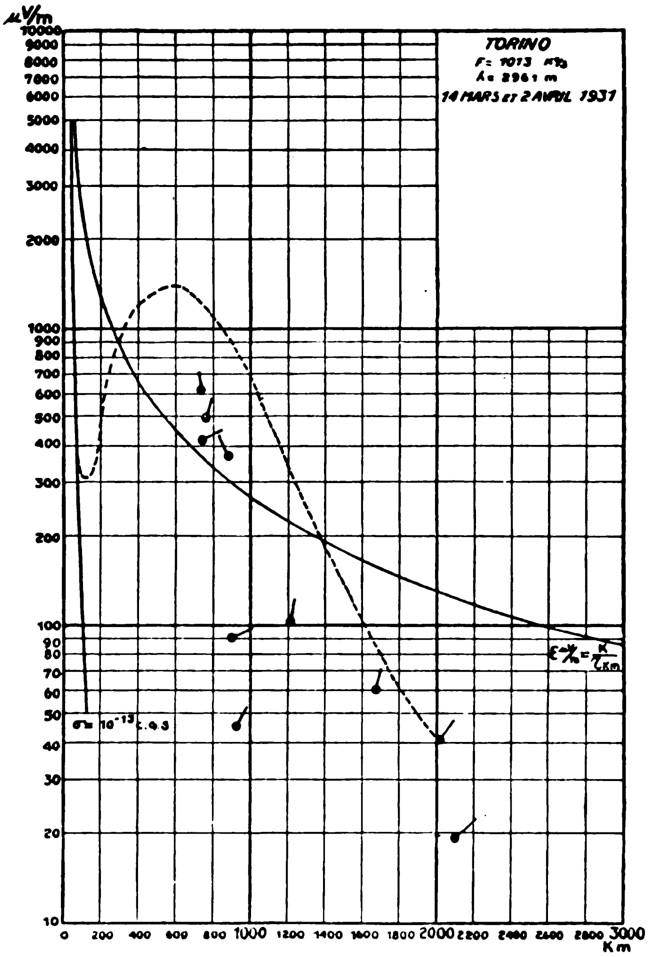

FIG. 32.

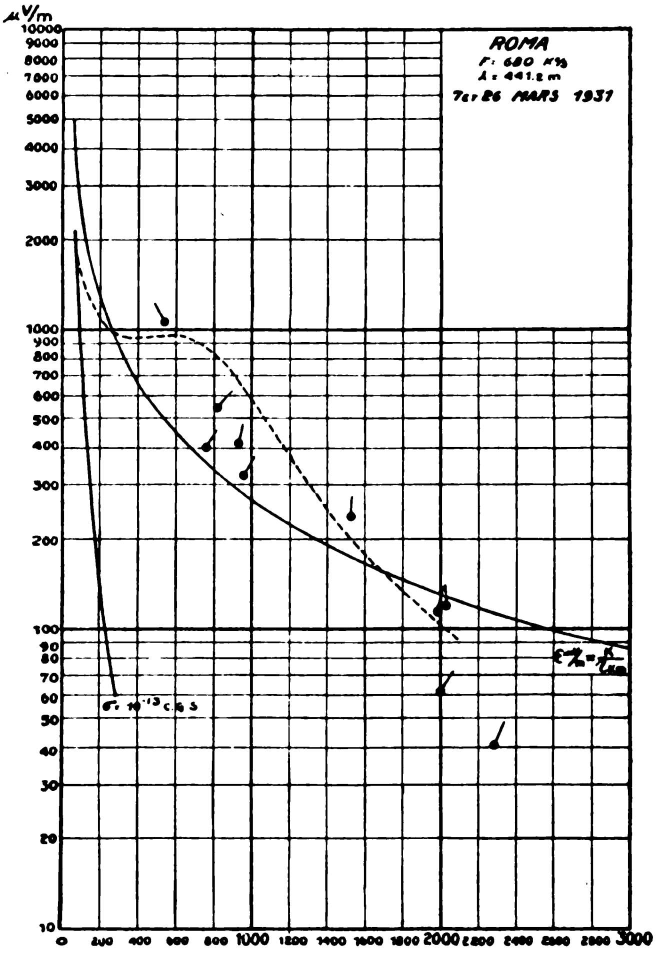

FIG. 33.

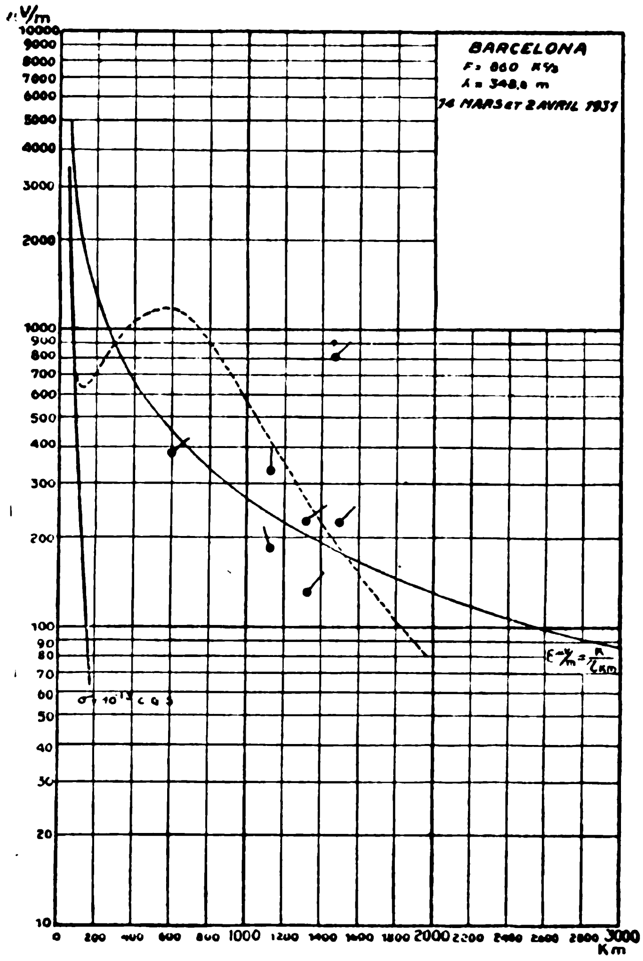

FIG. 34

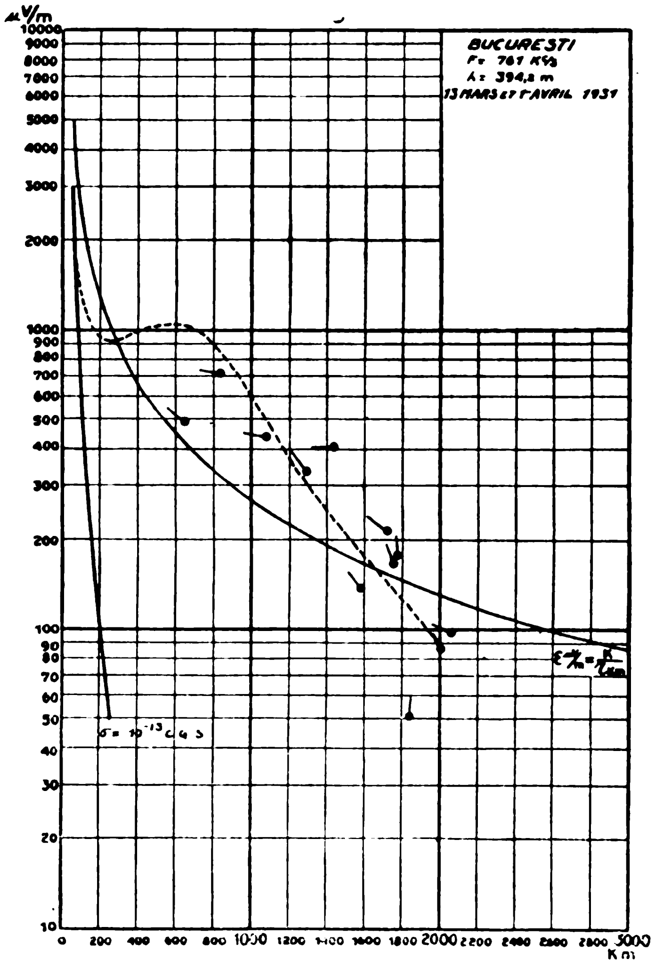

FIG. 35.

ANNEXE III.

SOLAR AND RADIO RELATIONSHIPS.

In the following discussion, the disturbances in terrestrial magnetism are considered to be the results of solar activity; therefore, the connection between magnetism and radio telegraphy is treated as a solar and radio relation.

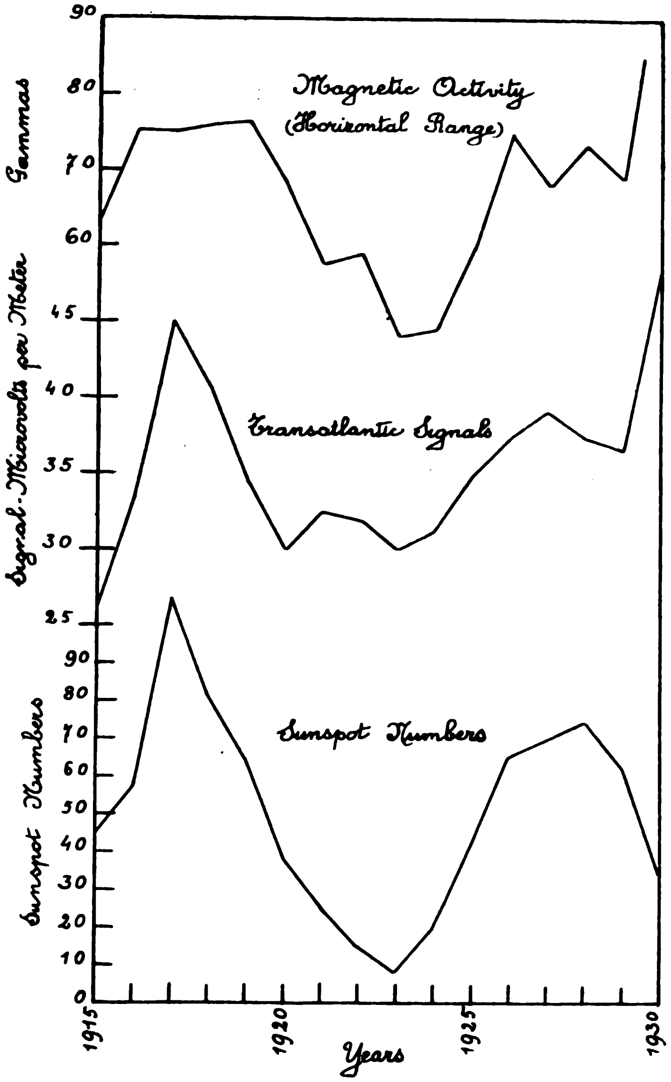

Fig 1

The first reference to an apparent connection between magnetic storms and radio signals is contained in an article by R. A. Fessenden [1] (1) in which he mentions that in some experiments carried on in 1906 between Brant Rock, Massachusetts, and a point in Scotland, the night signals appeared to become weaker after magnetic storms. The wave length was probably about 1.500 m.

The first detailed proof of magnetic and radio relationship is contained in an article by Espenschied, Anderson and Bailey [2] in 1926 where it was shown that transatlantic signals of about 5.000 m. wave length were weakened at night, while strengthened in the daytime, following severe magnetic storms. These experiments, while giving good evidence of the existence of a connection between terrestrial magnetism and radio signal strenght were somewhat unsatisfactory because the radio signal observations were taken only over week-ends and hence did not permit a complete study of the phenomenon.

Since 1926 considerable interest has been aroused in these relationships, but the problem has proved more intricate than was at first thought, on account of the differences of behaviour of waves of different lengths.

The effect of wave length may be roughly summarized as follows : In general the effect of magnetic storms becomes greater as wave lenght is decreased, [2], [9], [12], [13], thought below 10 m. very little is known. Between 10 and 60 m. wave length, even slight magnetic storms are found to be generally accompanied by weakening of radio signals both by day and night. The signal depression usually reaches its lowest point on the day of the greatest magnetic disturbance and several days are required before the signals return to normal [12]. According to Maris and Hulburt [10], when a magnetic storm starts, only those short-wave radio paths are affected which lie ont the daylight side of the earth, those on the dark side remaining quiescent until dawn; their theory being that both magnetic storms and radio signal disturbances are produced by flashes of ultra violet light from the sun. The experience of the U. S. Navy seems to support the radio portion of this hypothesis to a considerable extent. Short wave radio circuits running east and west are generally more affected by magnetic storms than those running north and south and the effect is greater the nearer the signal paths lie to the magnetic poles. T. L. Eckersley [15] states that the number ef periods in the year from October, 1927 to October, 1928 in which magnetic storms rendered short-wave communication impossible between England and Montreal were 49; between England and points to the southward, in Australia, South-Africa, India and South-America, these periods varied from 4 to 7.

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(1) References, p. 54.

Between wave lengths of 200 and 500 m., Pickard [3], [4], [5] has shown that a common effect of magnetic storms is a weakening of night signals. Thus far, there is no published information regarding magnetic effects on daylight signals in this wave length range.

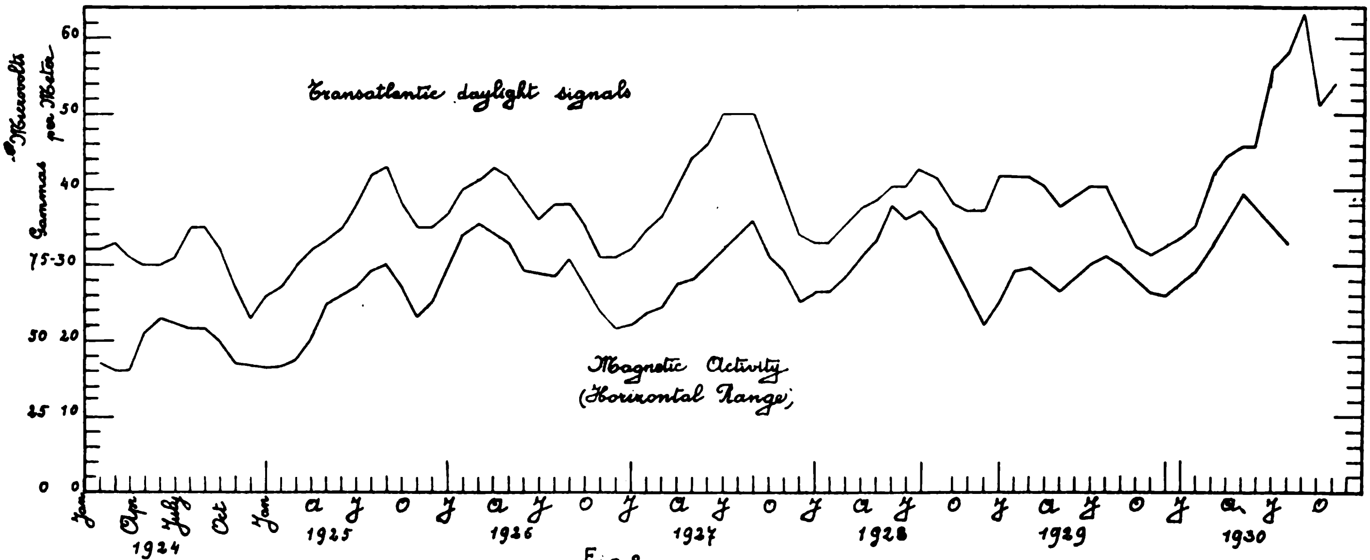

Fig 2

In connection with the transatlantic telephone, the American Telephone and Telegraph Company has shown that at a wave length in the neighborhood of 5.000 m., magnetic disturbances produce a daylight strengthening of the signals often amounting to from 30 % to 75 %, and a decided night depression, with a gradual return to normal conditions extending over several days [2], [9], [12]. The magnetic effect on the signals sometimes appears at the time of the storm but more often there is a delay of from one to three days.

For wave lenghts above ten thousand metres, the magnetic and radio relationship is much less noticeable [11], [17]. By statistical methods it may be shown that the daylight signals are slightly increased in strength by magnetic storms. Miss Wymore's [11] work indicates that the maximum rise of very long wave European daylight signals received in Washington comes as a rule from one to three days after the height of the storm. Too few observations on European stations have been made at the Bureau of Standards during the hours of all-darkness signal path to give any information regarding these relationships. The signals, having a path partly in daylight, received from Europe at about 3 p.m. E. S. T., appear to vary in general with the all-daylight signals of the morning reception. Some observations of the American Telephone and Telegraph Company [2], [9], however, indicate that magnetic storms produce night depression of signals even at 17.000 m. length.

Figures 1, 2 and 3 show the variation of daylight longwave signal strength between European stations and Washington and long wave atmospheric disturbances as compared with solar activity, when averaged over long periods.

Figure 1 shows the annual averages of sunspots, magnetic horizontal range measured at Cheltenham, Maryland, and the strength of dayligth European signals received at the Bureau of Standards from 1915 to 1930. The portion of the signal curve before 1923 represents reception from the 12.600 m. station, Nauen, (Berlin) only, measured by the shunted telephone method, and is only approximately accurate. Since 1923 the curve represents an average of several stations between 12.000 m. and 20.000 m. wave length with an estimated accuracy of 10-15 per cent.

Figure 2 shows a comparison of the combined curves of the same long-wave transatlantic stations and the magnetic horizontal range, when averaged by months and smoothed by three-month running averages. In figure 1, it is noticed that magnetic activity and signals both rise in 1930, while the sunspot numbers drop. The rise in magnetic activity, however, continued only through a part of the year, as shown in Figure 2, while the signal curve continued to rise and is still higher in April, 1931 than at any time since 1927. There seems to be no obvious explanation of this strengthening of the signals but it apparently is not connected with solar activity. As far as I know, no other daylight measurements of European signals above 10.000 m. wave length, which might serve as a check on the Washington observations, have been made in America during 1930. (All efforts to explain the increase in signal strength by possible changes at the receiving station have failed).

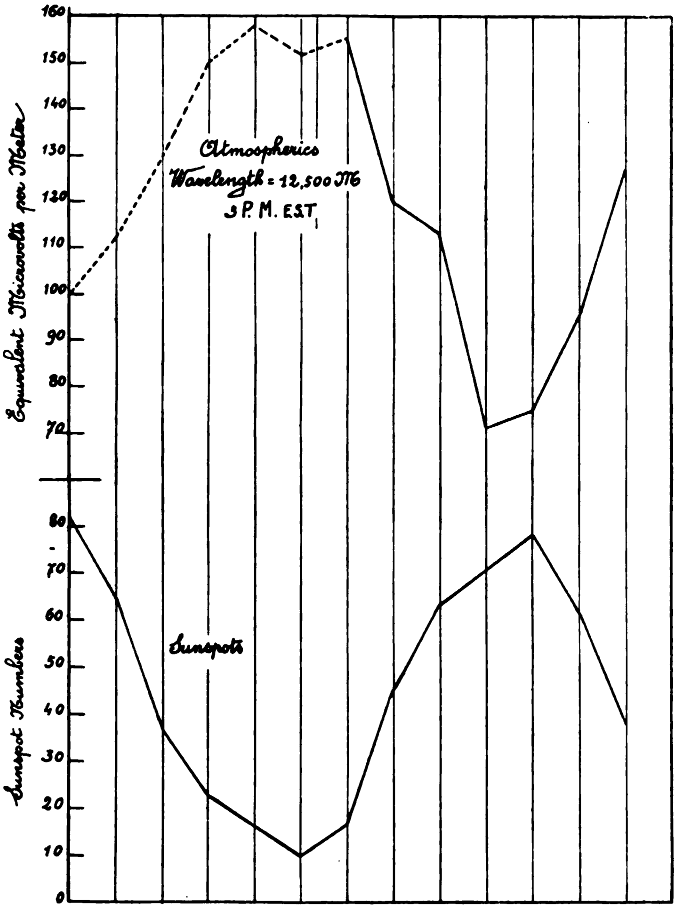

FIG. 3.

In Figure 3, annual averages of sunspots and long-wave atmospheric disturbances are compared. Between 1918 and 1924, the atmospheric curve is only roughly correct. The inverse correlation with sunspots appears to be even more distinct than the correlation between sunspots and signals. An attempt to show a solar and atmospheric disturbance correlation for shorter periods than a year has never been satisfactory, probably on account of the close connection between atmospherics and weather, which obscures the solar effect.

L. W. AUSTIN.

Chairman Commission II.

April 29, 1931.

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COMMISSION III. — PERTURBATIONS ATMOSPHÉRIQUES.

COMMISSION III. — ATMOSPHERICS.

INTRODUCTION.

La Commission des Atmosphériques est composée des membres suivants :

The Commission on Atmospherics is composed of the following members :

Président :	M. le Prof^{r} E. V. APPLETON, Wheastone Laboratory, King's College.
Belgique :	M. JAUMOTTE, Directeur de l'Institut Royal Météorologique; M. VAN HEMSTEE, Professeur à l'Université du Travail de Charleroi et M. le Général B. E. M. WIBIER.
États-Unis :	M. H. T. FRIIS, Bell Telephone Laboratories.
France :	M. le Commandant R. BUREAU, de l'Office National Météorologique; M. le Général G. FERRIE, Commandant Supérieur des Troupes et Services de Transmissions et M. le Prof^{r} ROTHE, Directeur de l'Institut de Physique du Globe.
Grande-Bretagne :	M. le Prof^{r} E. V. APPLETON; M. le Prof^{r} W. H. ECCLES, F. R. S.; M. le Colonel A. G. LEE, General Post Office et M. le D^{r} R. A. WATSON-WATT, Superintendant of the Radio Research Station.
Italie :	M. le Prof^{r} B. PAOLONI, Directeur de l'Observatoire Météorologique de Monte-Cassino et M. le Colonel L. SACCO, Directeur Principal de l'Office Radiotélégraphique et Electrotechnique du Génie Militaire.
Japon :	M. le D^{r} S. FUJIWHARA, Central Meteorological Observatory; M. le Capitaine M. HATTORI, Naval Technical Department, Ministry of Navy; M. T. NAKAGAMI, Bureau of Telephone and Telegraph Engineering, Ministry of Communications; M. SAEKI, Japanese Wireless Telegraph Company; M. le Lieutenant-Colonel T. YASUDA, Military Signal School et M. E. YOKOYAMA, Electrotechnical Laboratory.
Norvège :	M. le Prof^{r} V. BJERKNES, Professeur à l'Institut de Géophysique de Bergen; M. le Sous-Directeur O. DEVIK, Institut de Géophysique de Tromsoë et M. le Capitaine du Génie S. SKOLEM, de l'Administration des Télégraphes.
Nouvelle-Zélande :	M. le D^{r} M. F. A. BARNETT, Departement of Scientific and Industrial Research.
Pays-Bas :	Jr. P. J. H. A. NORDLOHNE, Secrétaire de la Nederlandsch Radio Genootschap et M. le Prof^{r} V. L. VAN DER BILT, Laboratorium voor Natuurkunde en Electrotechniek.
Portugal :	M. le Commandant N. RIBEIRO, Chef des Services Radiotélégraphiques de la Marine Militaire.
Suisse :	M. le D^{r} J. LUGEON.

COMPTE RENDU DES SEANCES. — ACCOUNT OF THE MEETINGS

1. — La Commission s'est réunie le lundi 1er juin à 16 heures et le vendredi 5 juin à 10 heures, sous la présidence de M. le Profr Appleton, Président de la Commission III. Ces séances faisaient suite à deux séances officieuses préparatoires : le vendredi 29 mai à 9 h. 30 et le lundi 1er juin à 9 h. 30.

2. — The *Chairman* nominated M. le Commandant Bureau as Vice-Président and M. Dr. R. A. Watson-Watt as Rapporteur. He also nominated M. le Commandant Bureau as representative of Commission III on the Polar Year Sub-Commission.

Ces désignations furent confirmées par la Commission.

3. — *Dr. R. A. Watson-Watt* submitted the report of the Sub-Commission appointed at Brussels to design and distribute apparatus for atmospherics research (¹).

La Sous-Commission fut accréditée à nouveau; il lui fut adjoint un nouveau membre, M. le Dr. L. W. Austin.

4. — The *Chairman* then delivered his address on « Some Observations on International Research on Atmospherics (²) ».

5. — Le *Commandant Bureau* présenta et expliqua les propositions du Comité National Français relatives aux travaux internationaux sur les Atmosphériques, en attirant spécialement l'attention sur l'Année Polaire; ces propositions ont trait aux points suivants :

I. — *a*) que soit établie une liste de toutes les stations assurant actuellement l'enregistrement des atmosphériques ainsi que les méthodes employées;
b) que soit établie une liste des stations dont l'installation n'est pas encore réalisée;

II. — que soient fixées des fréquences (longueurs d'onde) universelles pour l'enregistrement des atmosphériques;

III. — que soit organisé l'échange rapide sous forme graphique du résultat des enregistrements entre les stations participantes;

IV. — que soient prévues pour l'Année Polaire, en plus des enregistrements permanents, des observations spéciales et exceptionnelles, et en particulier que soient choisis des « Jours radios internationaux » en liaison avec les « Jours internationaux » de l'Année Polaire.

Première proposition. — M. le Commandant Bureau fut chargé de préparer la liste prévue par la première proposition; une Sous-Commission, composée de MM. le Commandant Bureau et le Dr. Watson-Watt, fut chargée d'étudier la définition (spécification) électrique de chaque méthode, en vue d'aboutir à une définition applicable dans la pratique et destinée à faciliter la comparaison des résultats. Cette Sous-Commission a présenté un rapport provisoire à la seconde séance de la Commission (¹). A la demande formulée dans le rapport, la Sous-Commission fut reconstituée avec des membres plus nombreux et d'une compétence plus étendue; les membres désignés étant : MM. Appleton (ex officio), Bureau, Lejay, Lugeon et Watson-Watt; ses attributions sont indiquées dans le rapport précité.

Seconde proposition. — Les fréquences suivantes (qui ne sont pas dans l'ordre de préférence) furent recommandées :

12 kc/s. 50 kc/s. et 90 kc/s.

Troisième proposition. — Il fut admis que l'échelle de temps déjà en usage dans l'échange des résultats graphique entre Paris et Slough, c'est-à-dire 6 cm. par jour, serait généralisée.

(¹) Annexe I, p. 59.
(²) Annexe II, p. 60.

(¹) Annexe III, p. 62.

L'organisation des résultats fut confiée à la Sous-Commission ci-dessus désignée avec pouvoir de déléguer cette fonction à l'un ou l'autre de ses Membres.

QUATRIÈME PROPOSITION. — Elle fut renvoyée à la Sous-Commission polaire.

6. — *Dr. Watson-Watt*, on behalf of the British National Committee, deposited for information a « Report on Research on Atmospherics carried out in Great Britain from July 1928 to March 1931 » (¹) and « Notes on Apparatus for Research on Atmospherics » (²). The latter document was submitted not as a programme of work, nor as a subject of discussion *per se* but solely to provide data on the economic side of the work, to which reference might be made when any particular line of investigation was under discussion.

7. — *Dr. Watson-Watt* also presented on behalf of the British National Committee a note relating to the « Study of the Circumstances of Origin of Atmospherics » (³). This note asked for the collaboration of the Commission towards the more effective prosecution of investigations on the origin of atmospherics which the British National Committee is at present undertaking.

The four requests contained in the document were for :

A. Simultaneous observations in other countries by means of photographic or visual cathode ray direction finders.

B. The consideration of the desirability and possibility of the radiation of synchronising signals for timing in such experiments.

C. Notification from other countries, with the least possible delay, of the occurence of lightning flashes.

D. Assistance, in arrear, in examining the meteorological environment of places which have, by the radiotelegraphic observations, been indicated as the place of origin of atmospherics at a particular time. This assistance would be required only in reply to a definite application for data about a specific place and time.

DEMANDE A. — Des assurances furent données par les Comités Nationaux Polonais, Français et Américain qu'ils s'efforceraient d'organiser des observations au goniomètre cathodique en simultanéité avec les observations britanniques.

DEMANDE B. — Les Comités Nationaux Français et Américain s'engagèrent à étudier dans le détail la possibilité de transmettre les signaux de synchronisation demandés.

DEMANDE C. — Il fut admis que la Sous-Commission entrerait en relations avec l'Observatoire du Pic-du-Midi et avec les autorités suisses en vue d'obtenir les renseignements désirés.

DEMANDE D. — Après une discussion détaillée, au cours de laquelle le R. P. Lejay fournit les remarques contenues dans son « Projet de discussion sur les rapports entre les Orages et les Atmosphériques » (¹) la résolution suivante fut adoptée à l'unanimité :

« Que les mesures simultanées des changements permanents du champ électrique terrestre, des caractéristiques et des effets de brouillage des atmosphériques et des phénomènes d'éclairs visibles, soient faits en collaboration étroite dans le plus grand nombre possible de pays ».

La Sous-Commission fut chargée de préparer le projet des principales lignes d'une telle recherche. On décida qu'on demanderait à l'Assemblée Générale de sanctionner la communication officielle du programme détaillé au Comité Météorologique International et à l'Union Internationale de Géodésie et Géophysique, en accompagnant cette communication d'un appel très pressant de collaboration.

(¹) Annexe IV, p 65.

(²) Annexe V, p. 70.

(³) Annexe VI, p. 73.

(¹) Annexe VII, p. 73.

ANNEXES.

- I. — *Report on Sub-Commission appointed by Commissions III to design and distribute apparatus for Atmospheric Research.*
- II. — *Some Observations on International Research on Atmospherics.* — E. V. APPLETON.
- III. — *Premier Rapport de la Sous-Commission sur les Méthodes d'Enregistrement des Atmosphériques.*
- IV. — *British National Committee. — The Present State of British Research on Atmospherics.*
- V. — *British National Committee. — Notes on Apparatus for Research on Atmospherics.*
- VI. — *British National Committee. — Study of the Circumstances of Origin of Atmospherics.*
- VII. — *Projet de discussion sur les rapports entre les Orages et les Atmosphériques.* — R P. LEJAY.

ANNEXE I.

REPORT ON SUB-COMMISSION APPOINTED BY COMMISSION III TO DESIGN AND DISTRIBUTE APPARATUS FOR ATMOSPHERICS RESEARCH.

It has not been found possible for the sub-commission to meet since the Bruxelles meeting in 1928. The proceedings of the sub-commission have therefore been limited to a series of communications from Mr. Watson Watt, with replies by Mr. Snyder.

It was agreed that the former should supply details of the apparatus already built, and that the first set built in America should be tested at Slough.

Full descriptions and sketches giving a complete technical specification of the apparatus constructed at Slough for the study of the energy flux spectrum of atmospherics were dispatched to Mr. Snyder on October 17th 1928, and receipt finally acknowledged on April 8th 1929. The destruction by lightning of the first experimental apparatus set up at Schenectady was reported on this date.

The most recent report of the position is contained in a letter from Mr. Snyder dated november 14th 1930, as follows :

« Those static measuring equipments are still quite in the air. As I wrote you several months back, the work was stopped temporarily because of a rather acute business depression. Business is still rather dull and we have not been able to pick up as yet. I am hopefull that there will be a rather marked upward turn very soon at which time I hope we may finish up the work. It is after all high time that these equipments be out in service ».

The Chairman of the sub-commission asks that the commission should consider the desirability of re-appointing the sub-commission with an additional member.

R. A. WATSON-WATT.
Chairman of Sub-Commission.
27-5-1931.

ANNEXE II.

SOME OBSERVATIONS ON INTERNATIONAL RESEARCH ON ATMOSPHERICS.

1. — Before proceeding to consider the detailed proposals for future co-operative work on atmospherics, it seems to me desirable to survey briefly the present status of our knowledge of this subject noting, where we can, the progress which can be attributed wholly or partly to international collaboration. It is, without doubt, correct to say that the international programmes which we have set out for ourselves at our two previous meetings have not been carried out with the completeness we intended. But some progress has been made in this direction, and we ought to take note of it. At the same time we must also ask ourselves the reason for the incomplete fulfilment of our international programmes and from our examination learn how to plan better for the future. My own view is that perhaps our programmes have been too ambitious. If we can agree that this is so, the way to more successful future experiments is clearly indicated.

2. — As we were originally led to study the subject of atmospherics because of their interferent effects on radiotelegraphic receivers, it is well to recognize at the outset the recent changed orientation in atmospheric research. Some years ago a large amount of inventive thought was devoted to devising complicated and often highly ingenious devices for the elimination of atmospherics from wireless receivers. Largely due to the work of Dr. A. Koerts and Dr. J. R. Carson we have had to admit that the complete elimination of atmospherics is an impossibility. Even with ideally selective circuits a certain minimum of interference will be absorbed, and this minimum increases with increase of the frequency range necessary for signalling. We have, in fact, learned to look upon atmospheric interference as possessing an energy spectrum spread throughout a wide range of frequencies and, if we choose to operate our communication channel on any particular frequency band, we are necessarily exposed to the interference corresponding to this range of frequencies in the atmospheric spectrum. This means that when the nature of the atmospheric spectrum is known, the amount of interference may be calculated from the constants of the receiving installation. We have learned that we cannot eliminate atmospherics from our receivers. We have, however, also learned that we can minimise the effects of atmospherics by limiting the frequency response of our receivers so as just to include the frequency range necessary for signalling.

3. — The above remarks show that, from the point of view of the radio-engineer who is interested in the prediction and performance of a wireless service, we require to know the energy flux spectrum of atmospherics (and its diurnal and seasonal variation) for all azimuths. Such would be the complete atmospheric specification from a practical point of view.

Realising this, plans were formulated at our last meeting for measuring the atmospheric frequency spectrum (averaged for all directions, since an aerial antenna was proposed) at many points on the earth's surface. Unfortunately the progress we hoped for has not been made with this ambitious experiment but one measuring installation has been working for some time now in South-East England and has already demonstrated the great value of the information to be obtained by this method.

Even if it is still found impossible to proceed with this ideal experiment I would like to lay stress on the fact that, as agreed by our Sub-Committee last year, the method we proposed for measuring the atmospheric spectrum is one of the most suitable to adopt, even when observations are confined to a single frequency (i.e. to single ordinate on the Frequency-Energy curve). Only by using some such method can we attach a precise meaning to the much-used phrase « Strength of Atmospherics ».

4. — I now turn to consider Atmospherics as geophysical phenomena. Here the chief problem is to find (a) the position and (b) the nature, of the discharges responsible for the origin of the atmospherics. It is clear that one of the most powerful methods of finding the place in which atmospherics are originating at any given time is that involving directional recording. Here it is satisfactory to note that pen-writing directional recorders have been running now for some years at Slough (England), Lerwick (Shetland Isles), Aboukir (Egypt), Potsdam (Germany), Bangalore (India), and Lindenberg (Germany). By the interchange of data amongst these countries it has been possible to make deductions as to the prevailing direction of arrival of atmospherics in West and Nord-Western Europe. Unfortunately the deductions made from comparable data by different investigators do not agree, for M. R. A. Watson-Watt finds that « the predominant source of atmospherics for the whole world, at any moment, lies in a land where it is summer afternoon » whereas Dr. F. Schindelhauer concludes that the maximum disturbance travels in directions which lie along and at right angles to the earth's magnetic field. It seems to me highly important that this matter should be considered afresh because of its bearing on the fundamental problem of the place of origin ot atmospherics.

5. — The question of the effective range of atmospherics has been on more than one occasion the subject of international discussion. As was most certainly desirable, entirely different experimental techniques for tackling this problem were developed in France and in Great Britain, and for some time the deductions drawn from the observations did not agree, the French school maintaining a very limited effective range for atmospherics, while the British school were led to conclude that atmospherics produced interferent effects some thousands of kilometres from their source. Fortunatly, and largely due to the discussions between Mr. Watson-Watt and Commandant R. Bureau resulting from our last meeting, the differences due to the dissimular methods of measurement have been allowed for, and it is agreed by both schools that atmospherics may have exceedingly large ranges. It is, however, very desirable that further work should be done on the subject.

6. — I now turn to a section of atmospheric research the results of which have given rise to most profound differences of opinion. I refer to the subject of the nature of the discharge in which atmospherics originate. Are these disturbances of terrestrial or extra-terrestrial origine? If they are of terrestrial origin what is their usual meteorological environment? If they are found to be associated with thunderstorm conditions do they originate only in lightning flashes?

If we are to settle these questions it seems to me that we must go further than the energy flux spectrum measurements which we have decided give the radio-engineer the information he requires. We must not be satisfied with average-effect observations but must isolate the individual atmospheric and determine its characteristics. It will be seen that this means that our directional and intensity measurements must now be made with apparatus characterized by a much greater rapidity of response than that used heretofore. We must use a microscopic instead of a microscopic time scale.

In this connection I do not think I can stress too highly the importance of the cathode-ray direction finder, the idea of which was put forward some fifteen years ago by Mr. Watson-Watt and which has recently been developed by the Radio Research staff at Slough in Great-Britain. With a base line of suitable length the directions of arrival of a single atmospheric can be observed at two stations and from the intersection of the two directions the position of origin of this particular atmospheric deduced. Results of great importance have already been obtained by American workers (A. E. Harper and S. W. Dean) using this method and the region of Europe provides a most suitable laboratory for experiments using a more detailed network. At present, so far as I am aware, the only place where daily observations of this type are being made is at Slough (England) where the results are being compared with meteorological information.

In attempting to obtain information on the much-discussed subject of lightning as a source of atmospherics it seems possible that methods at present used by workers in atmospheric electricity for studying rapid changes of the earth's potential gradient might, with certain modifications, be applied for investigating the waveform of the electromagnetic-disturbance originating in a lightning channel. The chief modification required would be the use of some form of electrical records of rapid response, such as a cathode-ray oscillograph or high-speed electromagnetic oscillograph. Considerable progress in developing such methods has already been made by Dr. H. Norinder (Sweden). The great advantage of this type of experiment is that both the source and the resulting atmospheric are known. When the complete specification of the electric field change due to a lightning flash at a known distance can be given, our present-day knowledge of the transmission of wireless waves will enable us to predict the intensity of the atmospheric produced at much greater distances.

7. — The question of solar influence on atmospheric origin and propagation is another matter we ought to consider. This subject demands sustained measurements over a long period of years such as have been made by Dr. L. W. Austin to whom we are indebted for practically all our information up to the present. In planning an extension of such observations it is well to remember that we must think in a time-scale of decades.

8. — In concluding these brief notes perhaps I may remind members of our Commission that to plan international work does not necessarily mean to arrange for exactly the same type of measurements to be made simultaneously in different countries. Cooperative research may take different forms. The two dissimular ends of an experiment may lie in different countries. For example, the simultaneous observations on the electric field of a thunderstorm in one country might conceivably be linked up; if timing were sufficiently accurate, with the observations on the resulting atmospherics in another country.

E. V. APPLETON.
President, Commission III.

ANNEXE III.

PREMIER RAPPORT DE LA SOUS-COMMISSION SUR LES MÉTHODES D'ENREGISTREMENT DES ATMOSPHÉRIQUES.

1. — La Sous-Commission composée de MM. Bureau et Watson-Watt a tenu plusieurs séances; pour certaines d'entre elles, elle a eu l'assistance précieuse du R. P. Lejay et du Professeur Appleton.

2. — Elle a eu sous les yeux la première liste provisoire des stations susceptibles d'enregistrer dès maintenant les atmosphériques (¹), et elle note avec satisfaction que cette liste comprend 20 stations et près de 30 types d'appareils pour l'enregistrement des phénomènes des catégories suivantes :

1° Nombre d'atmosphériques dépassant un seuil;

2° Intensité intégrée de la perturbation;

3° Direction d'arrivée : a) moyenne; b) individuelle;

4° Forme d'ondes des atmosphériques individuels.

3. — La Commission prend comme ligne conductrice de son travail la remarque contenue dans le discours de son Président, remarque qui signale que la définition complète d'une perturbation atmosphérique serait fournie par un diagramme à quatre dimensions donnant les variations par rapport au *temps* du *flux* d'énergie des atmosphériques dans tout le *spectre* electromagnétique pour tous les *azimuths* : un tel diagramme devant être établi pour chaque station dans un réseau suffisant pour caractériser le phénomène.

4. — La Commission reconnaît qu'il faudrait, comme préliminaire nécessaire à une telle définition, établir pour chaque instrument enregistreur en service un diagramme correspondant à trois dimensions donnant ses réponses à des

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(¹) Voir cette liste, p. 63.

LISTE DES STATIONS SUSCEPTIBLES D'ENREGISTRER LES ATMOSPHÉRIQUES.

Pays.	Localité.	Phénomène enregistré.	Fréquence moyenne.	En fonctionnement depuis	Fonctionnement prévu pour	Remarques.
Angleterre.	Slough.	Intensité intégrée.	10 Kc/s ± 25 V	1926 (la fréquence a été modifiée plusieurs fois).		10=2,2/w/m
Id.	Id.	Direction moyenne (courbe aiguë-encre).	Id.	1930 (de 1920 à 1930 vieux modèle).		½ mm=7,5/w/m (loi du carré).
Id.	Id.	Direction individuelle (photo).	Id.	1930.		1 mm=3/w/m (?)
Id.	Id.	Forme d'onde (photo).	Id.	1931 (entièrement visuel).		1 mm
Ecosse.	Leuchars.	Direction individuelle (photo).	Id.	Mai 1931.		1 mm=3/w/m
Id.	Id.	Forme d'onde (photo).			Juillet 1931.	
Australie.	Sydney.	Direction individuelle (visuel).	Id.	1930.		1 mm=4,6/w/m
Id.	Melbourne.	Direction moyenne (courbe aiguë-encre).	10 Kc/s±750 V	1930.		½ mm=5/w/m (loi du carré).
Id.	Watheroo.	Direction moyenne (courbe cosinusoïdale encre).	15 Kc/s±750 V	1931 (?)		1 mm=100/w/m (loi du carré).
Etats-Unis.	Houlton.	Direction individuelle (visuel).	56 Kc/s±600 V	1930 (pas de programme fixe).		1 mm=6,3/w/m
Id.	Cape May.	Id.	10 Kc/s±600 V		Eté 1931 (programme inconnu).	1 mm=180/w/m
Id.	Lakehurst.	Id.	Id.	1929.		Id.
Id.	Washington.	Id.	Id.			
Allemagne.	Potsdam.	Direction moyenne.				Fonctionnement suspendu, mais susceptible de reprendre.
Id.	Lindenberg.	Id.				Id.

Pays.	Localité.	Phénomène enregistré.	Fréquence moyenne.	En fonctionnement depuis	Fonctionnement prévu pour	Remarques.
France.	Saint-Cyr.	Nombre par minute.	50 Kc/s	Juillet 1928.		Deux enregistrements sur deux seuils différents.
Id.	Id.	Id.	12 Kc/s	Juin 1930.		
Id.	Id.	Intensité intégrée.	50 Kc/s		Octobre 1931.	
Id.	Id.	Direction moyenne (courbe cosinusoidale photo).	Id		Septembre 1931.	Enregistrement pendant quelques semaines en 1930.
Id.	Id.	Nombre par minute.	750 Kc/s		Octobre 1931.	Quelques journées d'enregistrement en 1930.
Id.	Mont-Valérien.	Id.	50 Kc/s	Août 1926 (la fréquence a été modifiée plusieurs fois).		Essais d'appareils nouveaux; interruptions nombreuses.
Id.	Id.	Id.	90 Kc/s	Mai 1931.		
Chine.	Zi-Ka-Weï.	Id.	50 Kc/s		Janvier 1932.	Deux enregistrements sur deux seuils différents.
Id.	Id.	Directions et formes.	Id.		Juin 1932.	Au moins à certaines époques à déterminer ultérieurement.
Algérie.	Alger.	Nombre par minute.	Id.		Novembre 1931.	
Tunisie,	Tunis.	Id.	Id.		Id.	
Maroc.	Rabat.	Id.	Id.		Id.	
Sahara.	Tamanrasset (?)	Id.	Id.		Eté 1932.	
Pologne.	Jablonna près Varsovie.	Id.	Id.	Février 1931.		Installation complète avec radiogoniographe et oscillographe cathodique.
Suisse.	Rochers de Naye-sur-Montreux.	Id.	Id.	A fonctionné de décembre 1929 à décembre 1930.	Août 1931 (?).	
Japon.	Tokyo.	Id.	22 Kc/s	Juillet 1927.		(A l'observatoire central météorologique.)
Id.	Hiraiso près de Mito (Harakiken).					(Station expérimentale du Ministère des Communications.)

champs qui lui seraient appliqués et qui varieraient dans la plus grande étendue possible (idéalement dans la totalité) de l'échelle des amplitudes, des fréquences et des azimuths.

5. — Elle note qu'à présent les stations Américaines et Britanniques seules, sont susceptibles de donner une approximation de ces diagrammes de réponse et que, seules, pour l'instant, elles disposent de moyens leur permettant de faire des mesures aussi détaillées. Par conséquent les listes provisoires contiennent la valeur des échelles pour l'amplitude et l'indication de la fréquence sur laquelle sont centrées les bandes ainsi que la largeur de ces bandes, pour les appareils fabriqués en Amérique et en Grande-Bretagne, mais elles donnent seulement les valeurs d'échelle pour les nombres, sans indications de la largeur de la bande pour les appareils fabriqués dans d'autres pays.

6. — La Commission n'a pas encore eu le temps de discuter tout au long les problèmes véritablement compliqués de la définition des appareils (spécification) problèmes qui impliquent l'étude de la distribution de la sélectivité dans les circuits qui précèdent et dans ceux qui suivent le point (qui idéalement se trouve uniquement au détecteur) où il se produit un écart sensible par rapport à la réponse linéaire (Phénomène de « cross modulation » etc.).

7. — La Commission demande que son mandat lui soit prolongé, avec addition possible de membres, de manière à lui permettre de compléter la liste définitive des enregistreurs et d'étudier le problème de la définition des appareils (spécification).

8. — En attendant la Commission propose les recommandations suivantes à la Commission III :

A) Que l'on demande au Comité National Français de remettre au Comité National Britannique un Radiocinémographe identique à ceux qui doivent être utilisés à Paris, Alger, Tunis et Zi-Ka-Wei.

B) Que l'on demande au Comité National Britannique de faire fonctionner cet enregistreur pendant une période considérable, à côté de l'appareil britannique.

C) Que l'on demande en outre au Comité National Britannique de mesurer le plus complètement possible les caractéristiques de cet enregistreur dans le sens du paragraphe **4** de ce premier rapport.

ANNEXE IV.

British National Committee.

THE PRESENT STATE OF BRITISH RESEARCH ON ATMOSPHERICS.

The state of British work on atmospherics was reviewed in reports to Commission III of the British National Committee under the following titles and dates, viz :

Summary of Recent British Work on the Nature and Effects of Atmospherics, 1926.

Summary of Recent British Work on the Intensity, Directivity, and Origin of Atmospherics, 1926.

A Review of the Present Position in British Work on the Nature and Origin of Atmospherics, 1926.

Appendices to these notes, April 1927.

Report on Atmospherics (supplementary to above), July 1928.

A review in a somewhat different form was read at the Public Session of the U. R. S. I. at Brussels, 1928, under the same title as the present note(1). This note is intended to bring up to date (March 31^{st} 1931) the type of information conveyed in these earlier communications.

Publications.

The amount of work published during the two-and-a-half-year period under review is regrettably unrepresentative of the work actually carried out. The only papers published in relation to the atmospherics programme of the Radio Research Board are the Symons lecture on « Weather and Wireless », Q. J. Roy. Met. Soc. **123**, **1929**, **500**; a series of

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(1) U. R. S. I., 1928, vol. II, fasc. 1, p. 119.

non-technical articles « About Atmospherics », World Radio, Jan.-July, 1930; the report of a discussion, at the Bristol Meeting of the British Association, on « The Meteorological Relations of Atmospherics », Q. J. Roy. Met. Soc. 125, 1931, ——; and the Report of the Radio Research Board for the period ending 31st March, 1929. No other British publications on atmospherics fall to be recorded, with the exception of letters in Nature, 126, 1930, 55 and 169 on « Submarine Cable Interference » in which preliminary comparisons between cable interference and atmospherics are discussed.

On the cognate subject of thunderstorm electricity the following papers should be noted, viz :

The Mechanism of Thunderstorms. (British Association Discussion.) (ENGINEERING 126, 1928, 495.)

SCHONLAND, *The Polarity of Thunderclouds.* (PROC. ROY. SOC. 118 A, 1928, 223.)

SIMPSON, *Lightning.* (J. I. E. E. 67, 1929, 1269.)

WORMELL, *Vertical Electric Currents below Thunderstorms.* (PROC. ROY. SOC. 127 A, 1930, 567.)

BANORJI, *Electric Field of Overhead Thunderstorms.* (Q. J. ROY. MET. SOC. 56, 1930, 305.)

SCHONLAND, *Thunderstorms and the Penetrating Radiation.* (PROC. ROY. SOC. 130 A, 1930, 37.)

In these circumstances the present note must take the form of an interim report of progress on the work in hand, but mainly unpublished, in the programme of the Radio Research Board. For convenience the history of each item, from its inception, is very briefly summarised.

Directional Recording.

The network of simple directional recorders installed at Aldershot (1921) Lerwick, Slough, Aboukir and Bangalore (1924), were maintained in operation until the end of 1928, when recording was suspended because it was considered that sufficient data of the type which this instrument could provide had been obtained. Similar recorders were operated for some time at Lindenberg and Potsdam Observatories by the Prussian Meteorological Institutes and results communicated to the Board's workers.

The resulting records were reduced to hourly predominant directions of arrival at all stations. Despite difficulties due to the very wide polar curve of the apparatus, and to the ambiguity of sense in the recorded bearings, the plotting of these hourly values resulted in the production of a world map showing the orderly progression of a single dominant source across the world, under solar control; the average source dominating atmospheric disturbance on long waves at European and North-African stations was shown to be in a land area where the season was local summer and the time of day local afternoon or evening. Thus for example the dominant sources in January lie over Southern S. America at 3 a.m. G.C.T.; the East Indies at 6 a.m. and 9 a.m.; are scattered over Europe between noon and 6 p.m.; and are again over S. America at Greenwich midnight. The corresponding positions in July are : 3 a.m. India and Tibet; 6 a.m. the region of the Caspian; 9 a.m. and Greenwich noon Eastern Europe; 3 p.m. to 9 p.m. Western Europe; and midnight Tibet.

Independent comparison of the data showing the most frequently disturbed directions for every hour of the day at different seasons shows very satisfactory agreement with data of average thunderstorm activity, the most frequently disturbed direction for any time and season, at any receiving station, passing through the most active thunderstorm centre of that period, allowance being made for attenuation effects due to distance and conditions of illuminations on the route from thunderstorm centre to recording station.

These examinations of the data in the mass were accompanied and supplemented by the examination of simultaneous observations at the recording stations on selected individual occasions. The known imperfections of the apparatus made exhaustive investigation on these lines unjustifiable, and it was considered sufficient to show that there was a general relation between individual sources of atmospherics thus located and cold fronts revealed by the meteorological charts.

To eliminate the more obvious disadvantages of the older pattern of directional recorder, a new pen writing recorder with a much more satisfactory polar curve has been developed and tried. Briefly, this new « narrow-sector » recorder consists of two independent aerial and amplifier systems, of which one may, for example, be a non-directional aerial with an amplifier of moderate gain, the second an aerial with a figure-of-eight or a cardioid diagram associated with an amplifier of much higher gain. These two operate differentially on the pen-writing indicator, so that the former is prevented from recording except when the latter is sensibly free from signal emfs., i.e. when it is passing through a direction of minimum disturbance. The nett effect is an inversion of the polar curve of the second aerial system, record being obtained only over a narrow sector centered on the minimum of the polar curve, and the sector of recording is deduced as the ratio of the gains of the two amplifiers is increased. The « resolving power » in respect of simultaneous streams of atmospherics arriving from different directions is thus very greatly increased, although at the expense of a restricted sampling of the whole distribution, recording taking place over a relatively small fraction of each revolution. Apart from the obvious direct improvement in resolution in azimuth the resulting records show a secondary improvement, which was forecast by the designer, in that the times of effective beginning and ending of activity of any particular source can be clearly discerned in the improved records; these additional characteristic quantities will very greatly facilitate the comparison of simultaneous records from different stations.

There is secure ground for the belief that the « narrow-sector » recorder will provide an easy means for the elucidation of many of the oustanding problems on the origin of atmospherics. One recorder of this type has been in experimental operation, at Slough since April 1930, another has been supplied to the Australian Radio Research Board.

The Cathode Ray Direction-Finder.

The cathode ray direction-finder, suggested in 1916, produced in 1923, reduced to a convenient form in 1927, and greatly improved in convenience and scope of application between 1927 and the present time, remains alone as a direction-finder capable of giving substantially complete sampling of any distribution of atmospherics within its limits of sensitivity and frequency-band. This high performance, based on its power of indicating the direction of arrival of each individual atmospheric has, until now, been capable of attainment only at a prohibitive cost in personnel, because of the fact that it has been left in the form of a visual instrument. Such sampling as has been possible, however, has been very instructive.

For a considerable period only one instrument of the kind existed, and direct comparisons of its indications with visible lightning were made. The next step in its application was its use in the identification of the particular atmospherics which actually proceeded from the dominant source, at particular times, located by the recorder network, and the study of the meteorological origins and the effective disturbing range of the atmospherics so identified.

In 1927 simultaneous observations with two instruments, one at Slough and one at Cupar, Scotland, with a direct line telephone connection between the two observers, were instituted. A preliminary comparison of the results with meteorological data confirmed and amplified the deductions drawn from recorder data, but showed that the details of the relation between cold fronts and sources of atmospherics were not all transparent, and that their elucidation would demand much closer study of the meteorological situation than could be made by anyone other than a specialist working in a modern forecasting centre. Arrangements were therefore made for daily telephonic reporting in code to the Airship Meteorology Division of the Meteorological Office, Air Ministry. This comparison is not yet complete, owing to the necessity for rechecking the records in cases where negative results appear to be indicated. The first indication is that approximately half of the radiotelegraphic locations agree with the indications of the meteorological chart, the remaining cases ought to be re-examined from the meteorological and from the observational standpoints. It is, however, doubtful whether, in view of the further progress now to be recorded any exhaustive re-examination is justified.

It was known that the method of observation employed, involving two stations only, each with a single observer making angular determinations on a scale of some five to ten centimetres diameter, the observers communicating by telephone for the maintenance of simultaneity of observation, would give a considerable proportion of fallacious locations owing to personal error. Irrespective of the ultimate method of observation in any practical application of the method, it was clearly desirable to eliminate personal error from any crucial experiments carried out to test the method.

A step towards this ideal was made with the introduction of photographic methods. The von Ardenne oscillograph (referred to in the following section on Wave Form work), enabled photography of the individual traces from the cathode ray direction-finder to be effected. After a considerable series of development tests, a satisfactory technique for simultaneous photography has now been evolved, and will be tested in daily use on the 500 km. base line Slough-Leuchars (Fifeshire), with telephone linkage for synchronisation and control, during the coming summer (1931). The locations made by this system are those which it is proposed to report for weekly broadcast issue under the auspices of the U. R. S. I.

Wave Form Work.

The visual observations of the wave form of individual atmospherics, began at Aldershot in 1922, continued in Aldershot, in H. M. S. « Yarmouth », in Helwan and Khartoum in 1923-24, yielded 50,000 individual drawings of atmospherics which have all been measured, reduced, and classified. Broad general conclusions have been drawn, and widely quoted and discussed but this great mass of data still awaits publication in detail and in final form. It is the more important that publication should be made because only one other worker, (Cairns at Watheroo) has succeeded in delineating even one thousand forms. Recently Joscheck at Halle has photographed wave forms with a mechanical oscillograph but his discussion, of results meagre in number, is completely invalidated by his failure to realise that he was recording a first differential $\frac{dE}{dt}$ and treating it as fundamental form E despite the emphasis laid on this point in the publications dealing with the work under the auspices of the Board.

The production of a greatly improved cathode-ray oscillograph, capable of operation from 300 to 4,000 volts, by Baron Manfred von Ardenne of Berlin, has brought the photography of the wave-forms shown on the normal apparatus into immediate practicability. Preliminary runs have been made, and it is satisfactory to note that the general nature of the recorded forms is in full agreement with the results of the « eye-and-hand » work.

It is to be expected that the application of the photographic method at two or more stations will give a great extension of data on the form of atmospherics, its modification during propagation, and the temporal incidence of atmospherics. It is proposed to develop the method of simultaneous photography of wave-forms at Leuchars and Slough as a preliminary to simultaneous photography over longer bases.

Energy Spectrum of Atmospherics.

The formidable difficulties of predetermining the disturbance to be expected in a given receiver at a given place and time by synthesis from wave-form and succession-interval data, led the Board to initiate an experimental determination, by a kind of wireless spectrometer, of the distribution of the energy of atmospheric disturbance throughout the wireless signalling spectrum. The first experimental element was set up in July 1926; a complete installation with six elements (each corresponding to a « slit » of different frequency centering but of constant width) was set up in April 1927 but was destroyed by fire in December 1927. A modified design was made and an experimental element set up in July 1928. Meanwhile, however, the International Scientific Radio Union at its Brussels meeting in 1928 had adopted the proposals, originating at Radio Research Station, for the international use of such instruments, and the General Electric Company of America had undertaken to provide thirty-six completed six-element installations free of charge to the Union. The Superintendent of the Radio Research Station and a representative of the General Electric Company were appointed as a special commission to design and issue the sets. In these circumstances the Board decided to suspend production of sets at Slough, pending the test of the first American set which was to be submitted to Radio Research Station for approval. No progress can be recorded in this item of the U. R. S. I. programme, nor has any definite statement of the General Electric Company's position and policy in the matter yet been received. It is hoped however that such a statement may be available at Copenhagen.

Data has been obtained in test runs on the following frequencies during the periods shown, viz :

July 1926 to January 1927 . .	12 kc/s.
April 1927 to November 1927	14 kc/s., 33.5 kc/s., 63 kc/s., 97 kc/s.
July 1928 to September 1929	13.2 kc/s.
September 1929 to present date	85 kc/s.

This material has been reduced to hourly (more recently to half-hourly) values, expressed in microvolts per metre of sustained signal at the central frequency of the band recorded, and harmonic analysis of the reduced values carried out. Similar treatment was accorded to the less satisfactory data of intensity of disturbance derived from limited portions of the material from the directional recorders. A group of preliminary notes have been prepared on some aspects of these reductions, and it is hoped to unite them into a single paper, with a view to publication, at an early date. Meanwhile it may be noted that the coefficients determining the amplitude of the terms in the series showing the diurnal variation of disturbance have been shown to have themselves an annual variation which is sufficiently nearly sinusoidal; that the diurnal variation curve of a random day can be very closely forecast from a single measured value of disturbance at any hour of that day, and that the form of the diurnal and annual variations is in agreement with the « long-range convective-origin » hyopthesis of atmospheric disturbance indicated in the section on directional recording.

Preliminary observations have also been made on the relation between disturbance level and mean frequency. The absolute level of atmospheric disturbance has a minimum in the region of 60 kc/s.; this fact is of special interest as agreeing with the determination made, in experiments on the Transatlantic Telephony service, that the « signal-to-static » ratio in these experiments reached a maximum about this frequency.

It has also been observed, in preliminary examination of these records, that the nature of the relation between atmospheric disturbance, on the relatively low frequencies examined, and terrestrial magnetic activity, is that the curve of atmospheric disturbance has brief intervals of abnormally high value when the rate of change of magnetic intensity is abnormally high. This relation cannot, however, be traced in every case, with the somewhat superficial means of comparison readily available. It is hoped that such data may be more closely examined in relation to records of rate of change of vertical magnetic force.

Effective Disturbing Range of Atmospherics.

The Board collaborated with a special committee of the Royal Meteorological Society in investigations on the effective disturbing range of atmospherics. Broadcast talks were used as time bases for observations by amateur observers, while the Board's network of directional installations fixed the sources of disturbance.

These experiments were so successful that the Board advised the Department of Scientific and Industrial Research to make available to the Royal Meteorological Society a number of picture-receiving installations, which have been in use since July 1929 in the recording of atmospherics received along with a special graticule transmitted, four times weekly, by the British Broadcasting Corporation using first a picture transmitter lent by Messrs. Wireless Pictures (1928) Ltd., and more recently a mechanically operated transmitter. In the earlier tests a considerable number of amateurs contributed records from their own picture receivers, but the cessation of normal picture transmissions has deprived us all save a very few — although an exceptionally valuable few — of these collaborators. The work of the observers has also been made more difficult by this cessation, as they are left without routine transmissions on which to test and adjust their receivers.

The broad results obtained up to date is that a very great preponderance of atmospherics are received at all stations where the receiver sensitivity — determined and indicated by the strength of the graticule signals — is sufficient to reveal them. In a number of cases it has been shown to be possible to determine roughly the path difference between the graticule and a particular atmospheric in reaching several stations, and thence to infer the approximate position of the source.

Up to the present the experiments have been regarded as preliminary only, but it is considered that the results justify a more comprehensive scheme, in which simultaneous observations on direction of arrival and on wave-form are made at Slough and Leuchars during these special transmissions. International collaboration in this simple programme would be valuable.

One important matter relating to the wave-form work has been strongly re-emphasised by the picture-recording experiments. It has always been realised that the wave-forms delineated are necessarily withdrawn from their context in the general stream of disturbance, and that the nature of the disturbances producing sounds of long duration in receivers required closer examination. The picture records, however, show with great clearness the frequency with which virtually uninterrupted streams of disturbance persist for periods of the order of a whole second. It is fortunate that the photographic technique for wave-form recording provides the means for examining the details of such disturbances.

Net Field Changes.

Experiments are in progress at King's College, London and at Radio Research Station, Slough on the semi-permanent changes in the earth's electric field which are produced by lightning discharges. The relation between this « electrostatic » term and the « radiation » term in the field changes due to lightning has been briefly discussed in the papers of Appleton, Watt and Herd on « The Nature of Atmospherics ».

ANNEXE V.

British National Committee.

NOTES ON APPARATUS FOR RESEARCH ON ATMOSPHERICS.

The British National Committee thinks that it may be useful for Commission III to have at its disposal notes showing the actual cost of the various types of apparatus already in use in atmospherics research in Great-Britain. It submits these notes, not as a programme of work, nor as a subject for discussion per se, but solely to provide data on the economic side of the work, to which reference may be made when any particular line of investigation is under discussion.

I*a*. — *The continuous recording of the Energy Spectrum of Atmospheric by the methods approved at the Brussels meeting of* 1928. The cost of the complete apparatus for a single station recording on six wave-lengths simultaneously is £ 700. The apparatus requires five hours of a scientist and five hours of a technical assistant per week for maintenance and running. The reduction of the records to half-hourly mean values requires thirty hours of a computer per station per week.

I*b*. — In the event of the full scheme being unattainable recording with a single element would cost £ 135, the attendance for two hours per week of a scientist, two hours of a technical assistant, and for reduction of data six hours per week of a computer.

II*a*. — *Photographic recording of directions of arrival of individual atmospherics*. The Chairman of Commission III of the British Committee hopes to have the opportunity of describing briefly in Public Session the technique of photographic registration with the cathode-ray direction-finder. The cost of the complete apparatus for a single station, including the apparatus for superposition of synchronising signals, is £ 500. The cost of running is so directly dependent on the magnitude of the programme that no firm estimate can be given, but two technical assistants are required during actual operation. The photographic processing of the film occupies a technical assistant for about one hour per period of observation, the full extraction of data occupies a computer for five hours per minute of observation. The more superficial reduction for location of the most prominent sources only could be carried out, at a central station, in two to three hours per period of observation per pair of stations. The British national programme at present provides for ten minutes per day on five days per week. The cost of film is likely to be about £ 1.10 sh. 0 d. per week for this larger programme.

II*b*. — A somewhat less expensive model could be designed to work on an approximately fixed frequency, preferably of 10 kc/s., at a reduction of £ 100 per station in cost of apparatus. The British Committee will, if required, undertake to prepare designs for such a photographic installation to cost not more than £ 400.

II*c*. — Visual observations, while far less satisfactory than photographic may be valuable supplementary contributions, and could be made at a cost of approximately £ 90 per station below the estimates gives above, viz. at £ 410 for the most sensitive sets of variable wavelength, or £ 310 for the less sensitive fixed wavelength set.

III. — *Synchronous photographic registration of the waveforms of individual atmospherics.* The apparatus, which is most conveniently operated simultaneously with the cathode-ray direction-finder cost £ 200 per station. The maintenance, running and photographic processing are similar in cost to those of II*a*, the reduction occupies about six hours per minute of observation. The cost of film may reach £ 1.10 sh. 0 d. per minute of observation, but is more normally about 2 sh. 0 d. per minute.

IV*a*. — The Radio Research Station has devised a new form of penwriting directional recorder whose discriminating powers in azimuth are much superior to those of the original recorder and which is free from the 180° ambiguity. This apparatus costs £ 320, and requires four hours per week attendance of a technical assistant, the records require four-and-a-half hours per week of a computer for reduction to hourly values.

IV*b*. — The older form of recorder can now be produced at a cost of about £ 230, but it is not considered that the data obtained are sufficiently complete to justify the use of these recorders otherwise than as subsidiary elements in a network.

V*a*. — In the region of much less expensive, but much less stringent observations, the British Committee would refer to the recording of disturbing range of atmospherics by the Fultograph receiving process. Transmissions are available from stations of the British Broadcasting Corporation, the cost of the receiving equipment is £ 15 per station, including the radio receiver, or £ 2 per station for the Fultograph apparatus at « scrap » prices. The present British programme involves four transmissions per week of four-and-a-half minutes each, the reduction of each record requires about two hours, this figure varies very widely according to the conditions of disturbance.

This recording scheme might be very widely extensed in geographical and wavelength range by utilising international or U. R. S. I. signals as synchronising signals for releasing the recording drum. By running the recorders at half the frequency of the « tops » in astronomical signals, a reliably measurable record could be obtained over about 70 % of the record, running at the frequency of the « tops » leaves the time scale indeterminate over the whole record, as no reference signal is thus obtained on the record itself.

V*b*. — Finally the Committee would refer to the aural observations on disturbance accompanying broadcast talks. The accuracy and value of this method was found to be very much higher than was ever anticipated by its promoters, and the fact that it can be operated substantially free of cost is in its favour.

In all cases the estimated costs above are the full economic costs of purchase as a whole or in parts from the cheapest reliable source or of construction in the workshops of the Radio Research Station, whichever is the cheaper. In the latter case the costs include general and special oncosts, but no development or research costs.

In conclusion, the Committee would again emphasise that these methods are put forward, not necessarily as the best methods nor as the only available methods, but as methods which have satisfied the British National Committee in actual use. Similarly the proposals are put forward not as a programme, but as an incomplete section of a catalogue raisonné of possible programme items for selection.

R. A. Watson-Watt.
Chairman of Commission III of the British National Committee.

ANNEXE VI.

British National Committee.

STUDY OF THE CIRCUMSTANCES OF ORIGIN OF ATMOSPHERICS.

The British National Committee asks for the collaboration of Commission III of the U. R. S. I. towards the more effective prosecution of the investigation on the origin of atmospherics which the British Committee has undertaken. It feels that, while the experimental methods for use in this investigation have been tested and found satisfactory, further progress is very largely dependent on extended international collaboration.

The Chairman of Commission III of the British Committee hopes to have the opportunity of describing briefly in public session the technique of simultaneous photographic registration with the cathode-ray direction-finder. This method is being employed in the location of sources of atmospherics by recording at two stations 550 km. apart, and the Department of Scientific and Industrial Research has undertaken to make the daily results of this work available for broadcasting in Ursigrams if desired.

The collaboration now asked for has several different aspects some of which may be conveniently handled by different collaborating organisations. The main difficulties in the study of the meteorological environment of the places of origin of atmospherics have been of two classes 1) imperfections in the radiotelegraphic data 2) imperfections in the meteorological data. The former, already reduced by the improvement of the method, can be further reduced by increasing the number of observing stations making simultaneous records. There remains, however, the limitation that economic considerations restrict the completeness of sampling, so that special arrangements are required to ensure recording at times of special meteorological interest.

The latter mentioned imperfections take the practical form that, despite the great volume of meteorological data ultimately available from national and international meteorological organisations the detailed data for a particular small area whose study is suggested by the radiotelegraphic locations are available only after laborious sifting of material, after considerable delay, and frequently still in insufficient detail.

The first request of the British Committee is therefore for simultaneous observations in other countries by means of photographic cathode-ray direction-finder. As examples of countries from which such collaboration would be specially valuable may be mentioned the United States, to deal with Atlantic sources, and Poland, to deal with Western European sources. Preliminary observations in England and America, approximately simultaneously, have shown the great value of such international collaboration.

The second request of the British Committee is for consideration by the U. R. S. I. of the desirability and possibility of the radiation of synchronising signals for the control of the timing on these records. The scheme at present in use over the land line connecting the two British observing stations might on rare occasions be extended to serve the proposed American station, but discussion of a practical method for further extension to frequent observations is required. The problem is especially difficult in the case of the special non-routine observations on occasions of exceptional meteorological interest.

The third request is for consideration of means by which these special occasions can be utilised. The type of collaboration here suggested is sufficiently indicated in a more general suggestion made at Bristol by the Chairman of the British Commission III, viz :

> « Let the Pic du Midi and the Zugspitze, observatories with good horizons and plentiful thunderstorms, signal by radio the instant at which a lightning flash is observed. Let Slough and as many other stations as can participate measure the peak voltages of the resulting atmospheric in aperiodic and in a series of band-filter circuits. Let the laws of propagation be applied to infer the peaks at other distances. Let the observatories measure the net field changes close to the discharge, and the specification will be complete for a wide range of normal receivers ».

The British Committee would undertake to make the fullest possible use of any such warning system as might be arranged, other National Committees would doubtless find it valuable for their own national programmes.

The fourth request is for assistance, in arrear, in examination of the details of the meteorological situation at places which have been, by the radiotelegraphic observations, indicated as the place of origin of atmospherics at a particular time. The British Committee asks for the advice of the Commission on the best methods for obtaining this detailed data.

R. A. Watson-Watt.

Chairman of Commission III
of the British National Committee.

ANNEXE VII.

PROJET DE DISCUSSION SUR LES RAPPORTS ENTRE LES ORAGES ET LES ATMOSPHÉRIQUES.

Ce n'est pas mon intention de vous parler de mes travaux sur ce sujet qui datent de plus de cinq ans.

Permettez-moi seulement, en vue d'amorcer une discussion, de poser un certain nombre de questions, de vous rappeler un certain nombre de faits expérimentaux et d'en tirer les conclusions qui me semblent propres à diriger nos débats.

Nous ne doutons plus qu'une des causes principales des atmosphériques, soit à rechercher dans les variations brusques du champ électrique de l'atmosphère, et nous voudrions savoir si ces variations brusques sont la seule cause des atmosphériques.

Nous savons d'autre part que l'éclair produit de ces variations brusques et constitue l'origine de certains atmosphériques à longue portée et nous voudrions décider si les éclairs constituent la seule cause des atmosphériques d'origine lointaine

En fin, quelle que soit la réponse aux questions précédentes sachant que l'éclair produit un atmosphérique à longue portée nous voudrions étudier la constitution de cet atmosphérique à l'origine, et le suivre au cours de sa propagation.

Pour répondre à ces questions nous disposons de faits expérimentaux qui peuvent être classés en deux catégories :

1° Les mesures directes de la perturbation orageuse au voisinage des éclairs vus par l'observateur;

2° L'identification à distance des sources orageuses d'atmosphériques enregistrées.

Les mesures directes, faites notamment par C. T. R. Wilson, par Nainder, et par moi-même, nous permettent de dire que l'éclair est une décharge de l'ordre de 10 à 50 Coulombs sous une tension de l'ordre de 300,000 volts par mètre au voisinage du sol, composée parfois d'éléments se succédant à une cadence plus ou moins régulière de l'ordre de quelques centièmes de seconde, chacun des éléments de structure très complexe ayant une durée totale de l'ordre du cinquante millième de seconde.

Mes mesures personnelles m'ont montré à 1 kilomètre de l'éclair des variations du champ

statique vertical de l'ordre de plusieurs dizaines de milliers de volts par mètre. A 20 kilomètres on observe encore des variations de 2 à 500 volts par mètre; à 150 kilomètres des variations de quelques dizièmes de volts par mètre.

Au calcul on doit déduire par conséquent que cet effet *statique* doit être encore de plusieurs centaines de micro-volts par mètre à 1,500 kilomètres.

D'autre part, à plusieurs reprises, j'ai observé des variations du même ordre de grandeur sans éclairs, au passage de cumulo-nimbus orageux.

Je donne en particulier à une observation un caractère très affirmatif car je le juge extrêmement important : j'ai mesuré une variation brusque de plus de 300,000 volts par mètre sans qu'il ait été observé, en pleine nuit, d'autre phénomène qu'un sifflement violent des paratonnerres et des aigrettes dans les cheveux des observateurs.

J'en conclus ainsi des observations de variations brusques de plusieurs centaines de volts par mètre à 20 kilomètres d'un cumulo-nimbus isolé dans un ciel clair, à l'existence dans l'atmosphère de décharges électriques violentes sans éclairs.

De la seconde classe d'expériences qui cherchent à localiser les sources d'atmosphériques pour en vérifier l'origine orageuse, on peut tirer les renseignements suivants :

L'expérience a montré, en particulier à M. Watson Watt que la majorité des centres d'émission d'atmosphériques se distribuent le long des surfaces de discontinuités météorologiques, et en particulier des fronts froids, où de fait se produisent aussi une grande proportion d'orages.

Mais il apparaît qu'une proportion variable suivant la saison, des sources d'atmosphériques ne se place ni à proximité d'orages, ni à proximité de cumulo-nimbus.

De ces faits expérimentaux il me semble donc qu'on puisse déduire cette conclusion.

Surtout si nous n'appelons éclair que le phénomène lumineux, généralement accompagné de tonnerre, on peut affirmer avec certitude que les atmosphériques ne proviennent pas uniquement des éclairs, mais les données que nous possédons ne nous permettent pas actuellement de nous faire une idée précise de la proportion des atmosphériques provenant des orages proprement dits.

Pour avancer dans le problème qui nous intéresse ici, il me semble qu'on pourrait envisager le développement simultané des deux méthodes. Il faudrait, comme l'a proposé la délégation britannique, essayer d'associer les observateurs d'orages et les observateurs d'atmosphériques et leur faire exécuter des observations simultanées.

Les difficultés que soulèveraient une telle expérience sont de telle nature qu'il semble difficile actuellement d'engager sur ce point une collaboration générale, mais on ne pourrait qu'applaudir à des ententes individuelles qui tendraient à mettre au point une méthode d'observation.

Il serait aussi très désirable qu'aux observations d'atmosphériques soient liées des observations des variations rapides du champ électrique de l'atmosphère soit par une méthode dérivée de celle qu'emploie C. T. R. Wilson, soit par la méthode qui consiste à mesurer le courant induit dans un cadre horizontal.

En conclusion, je proposerais les sujets de discussion suivants :

1° L'amélioration des observations d'orage (élaboration d'un projet à renvoyer au Comité Météorologique International) (altitude);

2° L'organisation de mesures physiques des variations brusques du champ électrique (projet à soumettre à l'Union Internationale Géodésique et Géophysique);

3° L'organisation de mesures individuelles de la perturbation électrique à grande distance de l'éclair, avec enregistrement à plusieurs distances pour l'étude de la propagation.

R. P. Lejay.

COMMISSION IV. — LIAISON AVEC LES OPÉRATEURS, LES PRATICIENS, LES AMATEURS ET LES SCIENCES CONNEXES.

COMMISSION IV. — COOPERATION WITH OPERATORS, PRACTITIONERS, AMATEURS AND CONNECTED SCIENCES.

INTRODUCTION.

La Commission de Liaison avec les Opérateurs, les Praticiens, les Amateurs et les Sciences Connexes comprend les membres suivants :

The Commission of Cooperation with Operators, Practitioners, Amateurs and Connected Sciences is composed of the following members :

Président :	M. le Prof^{r} A. E. KENNELLY of the Harvard Engineering School.
Belgique :	M. F. DACOS, Chargé de Cours à l'Institut Montefiore.
États-Unis :	M. le Prof^{r} A. E. KENNELLY of the Harvard Engineering School.
France :	M. P. BRENOT, Directeur de la Société Française Radioélectrique; M. le Général DELCAMBRE, Directeur de l'Office National Météorologique et M. le Lieutenant-Colonel JULLIEN, Directeur du Centre d'Études de la Télégraphie Militaire.
Grande-Bretagne :	M. O. F. BROWN, Department of Scientific Research; M. le Prof^{r} S. CHAPMAN of the Imperial College of Science and Technology; M. le D^{r} E. H. RAYNER, D. Sc., National Physical Laboratory; M. le D^{r} G. C. SIMPSON et M. le D^{r} R. A. WATSON WATT, Superintendant of the Radio Research Station.
Italie :	M. le Commandant G. MONTEFINALE et M. le Colonel L. SACCO, Directeur Principal de l'Office Radiotélégraphique et Électrotechnique du Génie Militaire.
Japon :	M. le D^{r} S. FUJIWHARA of the Central Meteorological Observatory; M. HASIMOTO of the Tokyo Astronomical Observatory; M. S. INADA of de Bureau of Telephone and Telegraph Engineering, Ministry of Communications et M. le Prof^{r} D^{r} H. NAGAOKA of the National Research Council.
Norvège :	M. le Capitaine F. BUGGE, Chef du Laboratoire Radiotechnique de la Marine; M. B. L. GOTTWALDT, Radiotechnisk Konsulent et M. NICKELSEN, Directeur Général des Télégraphes.
Nouvelle-Zélande :	M. le D^{r} M. A. F. BARNETT of the Department of Scientific and Industrial Research.
Pays-Bas :	Jr. G. SCHOTEL, Ingénieur au Bureau Technique du Ministère des Colonies et M. H. VEENSTRA.
Portugal :	M. le Lieutenant de Vaisseau F. PIRES da ROCHA, Chef du Laboratoire Radiotélégraphique de la Marine de Guerre.
Suisse :	M. le D^{r} J. LUGEON.

COMPTE RENDU DE LA SEANCE DU MARDI 2 JUIN

ACCOUNT OF THE MEETING OF TUESDAY, JUNE 2

La séance est ouverte à 16 heures, sous la présidence du Dr E.-H. Rayner.

Le *Président.* — Je regrette vivement que nous n'ayons pas parmi nous le Président de cette Commission, M. le Profr Kennelly, dont la science et la connaissance de la langue française auraient beaucoup contribué à la direction de ce débat.

Je me suis senti très honoré d'avoir été choisi par vous comme Président; j'essayerai de me rendre digne de cet honneur, mais je dois vous demander toute votre indulgence et toute votre assistance.

Nous devons élire un Vice-Président pour la Commission IV et j'ai l'honneur de vous proposer la candidature de M. le Profr Nagaoka.

Nous avons aussi à choisir un rapporteur et je propose d'élire à cette fonction M. le Profr Chapman.

Ces propositions sont adoptées à l'unanimité.

Le *Président.* — Je vais vous donner un court résumé du rapport de M. le Profr Kennelly, Président effectif de notre Commission (1).

Ce rapport attire l'attention de la Commission sur l'échange international d'informations relatives aux phénomènes cosmiques que l'on estime pouvoir influencer la propagation des ondes à la surface de la terre.

M. le Profr Kennelly divise les zones qui intéressent la transmission des ondes, en quatre couches :

1° Zone terrestre;
2° Zone atmosphérique inférieure;
3° Zone atmosphérique supérieure;
4° Zone ultra atmosphérique.

Le rapport attire également l'attention sur l'importance des observations et des mesures de la radio comme étant l'une des méthodes les plus puissantes et dont on puisse attendre le plus pour découvrir les propriétés des zones 3 et 4.

Le Profr Kennelly expose l'organisation du Service des « Ursigrammes » français qui a débuté en décembre 1928 et cite les postes émetteurs de ces « Ursigrammes ». Il donne aussi des détails sur l'organisation du service américain. L'auteur donne un code relatif à la hauteur de la couche ionisée et présenté au Comité National Britanniqu qui l'acceptera très volontiers.

L'aide importante fournie par le « Science Service » est signalée et je vous propose que la Commission IV suggère à l'Assemblée générale de prier M. le Profr Kennelly de présenter les très vifs remerciements de l'U. R. S. I. au « Science Service ». Plusieurs membres de l'U. R. S. I. savent que les organisations les plus importantes d'Amérique, aussi bien officielles que privées, fournissent des informations alimentant ce service.

Le Profr Kennelly signale également la publication en « clair » des « Ursigrammes » américains ce qui peut être très utile.

Il fait aussi remarquer que les informations fournies par le Comité National Britannique seront ajoutées aux « Ursigrammes » français, et seront transmises par des stations françaises pour des raisons exposées dans le rapport du Comité National Britannique (1).

Le Profr Kennelly suggère encore l'idée importante que, pour les mêmes raisons, toutes les autres informations cosmiques fournies par d'autres pays ne soient transmises que par les stations françaises. Ceci est un sujet qui devra être discuté par la Commission. Le professeur fait les mêmes suggestions pour l'Amérique du Nord et celle du Sud, et peut-être pour l'Australie.

La Commission sera heureuse d'entendre les idées des délégués du Comité National Japonais au sujet de la proposition ayant pour but de joindre le Japon à un tel service.

Enfin, l'auteur signale qu'une réunion officieuse de la Commission IV a eu lieu à Stockholm, à l'occasion de la dernière Conférence de l' « Union Géodésique et Géophysique Internationale »; au cours de cette réunion on a discuté des sujets d'intérêt commun à cette « Union » et à l'U. R. S. I.

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(1) Annexe I, p. 80.

(1) Annexe II, p. 85.

M. le Prof^r Kennelly m'a fait savoir qu'il serait à Paris et à Londres dans quelques semaines, et qu'il serait heureux de discuter les idées et les décisions de la Commission IV.

Je désire adresser à M. le Prof^r Kennelly les remerciements de la Commission IV pour le travail que lui a demandé la rédaction de ce rapport si intéressant et si utile.

Le *Général Ferrié.* — Le Comité National Français accepte de se charger du Service des Ursigrammes, si en agissant ainsi, il peut faire œuvre utile, mais si un autre Comité National le désire le Comité National Français lui cédera la place.

Le *Président* donne lecture du rapport du Comité National Britannique (¹), puis du Projet d'Organisation d'Émissions d'Ursigrammes du Comité National Français (²).

Le *Commandant Bureau* commente ce dernier document.

Prof^r Appleton. — Owing to the short time allowed between the reception of this paper and the present Assembly, I have not been able to study it, so I ask to the Members of the French National Committee if the French code is based upon the same principles as the American one.

Le *Commandant Bureau.* — Le principe en est le même, les renseignements transmis seuls varient; c'est pourquoi les codes employés sont différents.

Prof^r Appleton. — I thank you, it is all I wanted to know.

Le *Président* donne ensuite lecture d'une proposition du Comité National Britannique concernant l'émission des Ursigrammes.

Le Comité National Britannique est disposé à commencer immédiatement la radiodiffusion de ses rapports sur les centres d'observation des atmosphériques, et il propose de le faire par les postes anglais tous les samedis. Peut-être qu'ainsi les émissions par les postes français pourront être faites le lundi suivant.

Les positions seraient mesurées cinq jours par semaine (du lundi au vendredi), à 13 heures.

Le Comité National Britannique est également disposé à entamer des mesures journalières sur la hauteur des couches. La hauteur sera mesurée cinq jours par semaine (du lundi au vendredi), à 12 heures, et les résultats seront envoyés le samedi à Paris.

Les longueurs d'ondes utilisées seraient 80 et 170 mètres, si cette dernière onde est jugée utile.

Le *Général Ferrié.* — Nous allons avoir des émissions d'Ursigrammes en Europe et aux États-Unis, il serait utile d'en avoir également dans les autres parties du monde : au Japon, en Asie et en Australie.

Ces émissions devraient avoir lieu simultanément sur ondes longues et sur ondes courtes, ainsi qu'il est fait pour les signaux horaires (Pontoise sur 29 m. et Bordeaux sur 18,000 m.).

J'ajouterai que si un pays d'Extrême-Orient voulait coopérer à ce travail, il nous apporterait des renseignements précieux. L'Observatoire de Zi-Ka-Wei pourrait-il collaborer à ce travail?

Le *R. P. Legay.* — J'apporterai toute ma collaboration à ce travail dans la mesure du possible; c'est une question d'organisation. Je pourrais transmettre les renseignements sur ondes courtes par la nouvelle station de Chang-Haï.

Le *Président* sollicite M. le Prof^r Nagaoka de prendre part à cette organisation.

Prof^r Nagaoka. — Such a service would be very difficult to organize. A similar service for earthquakes was proposed, but we have so many that it would be difficult; and our radio stations have hardly an adequate range. The auroras have never been observed in Japan but troubles in radio wave propagation have been noticed.

Le *Président.* — Le Comité National Japonais n'est pas en mesure de nous fournir des renseignements, nous espérons cependant qu'il tiendra compte de notre désir.

Prof^r Nagaoka. — I promise to mention it to the Japanese Physical Commission and I hope that in a near future its cooperation will be obtained.

(¹) Annexe II, p. 85.

(²) Annexe III, p. 87.

Le *Président.* — Pour étudier les phénomènes de « skip distance », on a organisé pour le mois de juillet de cette année, sous la direction de M. le Commandant Bureau, des essais de réception des ondes de 4081-8162 et 9200 Kc/s émises par le poste de Paris (Eiffel) et de 5000 et 11450 Kc/s émises par le poste de Lyon.

Une trentaine d'amateurs anglais prendront part à ces essais.

Le *Commandant Bureau.* — Des expériences avec la collaboration des amateurs sont entreprises depuis des années; il importe que les personnes qui participent à ces expériences soient nombreuses. En Grande-Bretagne, un appel de M. le Prof^r Appleton a suscité 40 réponses. Pour la dernière série d'essais faite en France, nous avons pu réunir 285 collaborateurs de France et des autres pays. On s'est efforcé d'obtenir dans toutes ces expériences des renseignements sur les quelques points suivants :

Variation diurne de la propagation des ondes courtes; étude s'étendant à la plus grande surface possible et grande densité d'observations grâce à un grand nombre d'observateurs. Il faut toutefois s'assurer de l'exactitude des résultats, ce qui implique la nécessité de groupes de contrôle. Chaque poste récepteur est alors à même de tracer une courbe de variations diurnes.

Les principaux résultats sont les suivants :

a) Les points de réception forte, moyenne, ou nulle se groupent;

b) Les zones de silence sont rarement circulaires mais souvent dissymétriques, et varient avec l'heure, avec l'onde et avec la journée;

c) Des zones d'audition s'observent à l'intérieur de ces zones de silence;

d) Les zones de silence sont plus importantes pendant la nuit que pendant le jour, mais il arrive qu'elles évoluent en sens inverse de cette règle (par exemple : qu'elles se rétrécissent à la nuit tombante);

e) Les cartes qui peuvent être établies à l'aide des résultats permettent des comparaisons avec les cartes météorologiques.

On a pu ainsi mettre en évidence des relations entre la propagation et les phénomènes météorologiques.

En conclusion, il serait désirable que dans l'avenir, on s'assure l'aide du plus grand nombre possible de collaborateurs (services officiels et amateurs).

Le *Dr. Lugeon.* — La Pologne poursuit les mêmes recherches, le poste de Varsovie, qui est très bien placé, s'offre à faire des émissions simultanées ou chevauchantes qui seraient observées par le réseau d'écoute de M. le Commandant Bureau.

Le *Commandant Bureau.* — Il y a lieu de mettre à profit la proposition de M. le Dr. Lugeon; il faut cependant préparer le programme à l'avance, deux mois sont nécessaires pour ce travail, je suis à ce sujet à la disposition de M. le Dr. Lugeon.

Le *Président.* — Nous devons signaler l'importance de l'étude sur l'influence de la répartition de l'ozone dans les couches atmosphériques des ondes. Nous pouvons signaler l'organisation internationale au sujet de l'ozone atmosphérique et déclarer que l'on doit étudier la réception et les modes de réception des ondes en vue de savoir si ces phénomènes sont influencés par les variations de l'ozone. M. le Dr. Austin dit ne pas avoir trouvé de corrélation sensible pour ce qui concerne les ondes longues.

Quelqu'un a-t-il une remarque à faire à ce sujet?

On provoque de temps en temps des explosions artificielles pour étudier les propriétés de l'atmosphère au point de vue météorologique, je propose à la Commission IV d'étudier à ces mêmes moments, les propriétés électromagnétiques, à l'aide des différentes méthodes utilisées dans les stations où l'on étudie la réception de ces ondes.

Prof^r Nagaoka. — It would be interesting to use for this purpose volcanic explosions as those of the Krokatoa, for their residues modify completely the nature of the propagation medium.

Le *Président.* — Je remercie M. le Prof^r Nagaoka de cette suggestion qui est originale et intéressante.

Prof^r la Cour. — The wish had been expressed that the times of these explosions would be in concordance with the stated days for the investigations of the upper atmosphere. Those days are already fixed for next year.

Le *Commandant Bureau.* — J'ai essayé d'obtenir cette coïncidence, mais elle n'est pas possible pour toutes les observations. Toutefois, la mesure de la hauteur de la couche ionisée serait intéressante à réaliser ces jours-là.

Le *Général Ferrié.* — Le Comité National Japonais pourrait peut-être élaborer un programme pour l'étude de l'influence des éruptions volcaniques sur la propagation des ondes.

Prof Nagaoka. — I will designate a Commission to study such a program. There are other countries in the same situation as Japan, from an international point of view, it would be interesting to obtain their cooperation.

Dr. van der Pol. — Actually I am not authorized to talk of the cooperation of the Dutch East Indias but I will enquire and see what can be done.

Le *Président.* — Les membres du Comité National Italien peuvent-ils prendre cette remarque en considération?

Le *Commandant Ruelle.* — Je soumettrai la question à mon Gouvernement.

Le *Dr. Lugeon.* — L'Union Géodésique et Géophysique Internationale a voté à Stockholm en 1930, une résolution relative à l'enregistrement des ébranlements acoustiques dûs aux explosions des mines de fer en Suède. Ces enregistrements seraient heureusement complétés par des mesures de l'altitude des couches ionisées par les procédés radioélectriques faites aux mêmes moments. Pour avis aux expéditions de l'Année Polaire séjournant dans le Nord de la Norvège.

Le *Président.* — On a discuté dans d'autres Commissions et au cours d'une réunion officieuse de la Commission IV, ce sujet qui a une si grande importance pour les études physiques de notre globe : l'Année Polaire.

On choisira au cours de la séance finale de l'Assemblée générale, une Commission spéciale qui sera chargée d'organiser les observations des transmissions radioélectriques au cours de cette année polaire et il convient que la Commission IV nomme un délégué pour cette Commission.

Dr. van der Pol. — I propose to delegate Dr. Watson Wat.

Prof la Cour. — I agree with this proposition.

Cette proposition est adoptée aux applaudissements de la Commission.

Le *Général Ferrié.* — Nous devons aussi songer à un autre travail utile qui se fera en octobre 1933. A cette époque on procédera à une revision internationale des longitudes. Un grand nombre d'observatoires enregistreront des signaux transmis sur ondes courtes; il serait intéressant de profiter de ces enregistrements qui pourront fournir des résultats intéressants sur plusieurs points que nous étudions, notamment la vitesse de propagation. Les Comités Nationaux pourraient étudier cette question et avertir le Secrétariat Général afin que ces observations puissent être organisées. Peut-être vaudrait-il mieux avertir le Président de la Commission IV qui pourrait préparer le travail.

Le *Président.* — Pourquoi a-t-on choisi le mois d'octobre 1933?

Le *Général Ferrié.* — Cette opération a déjà été faite en 1926 et a donné des résultats de grande précision. Elle a pour but de déterminer les positions géographiques intéressantes et, éventuellement, les déplacements des continents. Il est utile de faire ces déterminations périodiquements, tous les sept ans.

En 1932, se réunit également l'Union Astronomique Internationale pour décider des méthodes à suivre en 1933.

On a choisi le mois d'octobre parce que c'est à cette époque de l'année que le ciel est le plus favorable à l'observation et cela pour la majorité des observatoires.

Le *Président.* — Je prie donc les Comités Nationaux d'étudier cette question et de tenir le Président de la Commission IV au courant de leurs décisions.

La séance est levée à 18 h. 15.

ANNEXES.

- I. — *Report of Commission IV on « Liaison », for the period between the General Meetings of 1928 (September 10-15th, at Brussels) and 1931 (May 27th, at Copenhagen).* — A. E. Kennelly.
- II. — *British National Committee. — The Present State of Liaison Work in Great Britain.*
- III. — *Comité National Français. — Projet d'organisation d'émissions d'Ursigrammes faites par les postes radiotélégraphiques français sous les auspices du Comité Français de Radiotélégraphie Scientifique.*

ANNEXE I.

REPORT OF COMMISSION IV ON « LIAISON », OF THE U. R. S. I., FOR THE PERIOD BETWEEN THE GENERAL MEETINGS OF 1928 (SEPTEMBER 10-15th, AT BRUSSELS) AND 1931 (MAY 27th, AT COPENHAGEN).

The attention of the Commission has been mainly devoted to the international radio exchange of cosmic data regarded as capable of affecting the propagation of radio waves over the surface of the globe.

The intensity of electromagnetic wave signals, received from distant parts of the world, is believed to be affected by a number of cosmic influences, which, for convenience, may be divided into four groups, by zones concentric with the globe :

(I) Terrestrial Zone.

Influences at or near the earth's surface, both above and below it, such as topographical configuration, forestation, structures and buildings above ground, as well as the physical condition of the surface water, soil, or rock, and the distribution of geological chemicals and moisture immediatly below the surface.

(II) Lower Atmospheric Zone.

Meteorological influences in the lower atmosphere or troposphere, including atmospheric electric disturbances.

(III) Upper Atmospheric Zone.

Upper atmospheric influences at elevations from say 10 Km. to 500 Km. above the earth, and the effects of ionised gases forming absorbing, refracting or reflecting layers, including auroras.

(IV) Ultra Atmospheric Zone.

Influences outside of the earth's atmosphere, such as solar activities.

In the opinion of many observers, radio researchs offer the most hopeful means of discovering the nature and properties of zones III and IV, as well as of their influences upon radio transmission.

At the Brussels meeting of September 1928, the recommendation was expressed that radiobroadcasts concerning geographical and astrophysical phenomena, possibly capable of affecting the propagation of radio waves, should be emitted daily from a certain small number of radio transmitting stations, so as to permit specialists to become speedily informed concerning the same.

French Ursigram.

On December 1st 1928, the French authorities commenced emitting a daily radio-bulletin or Ursigram from the Eiffel Tower at Paris, in plain (uncoded) French language, through international Morse code. For this important scientific innovation of the daily Ursigram, we are indebted to the efforts of our U. R. S. I. President, General Ferrié.

The French Ursigram (1) has continued to be appended at the end of a daily meteorological bulletin. It was issued under the joint auspices of the « Institut de Physique du Globe, de Paris », of the Astronomical Observatory of Meudon, and of the « Office National Météorologique de Paris ». It is composed of two parts :

a) Geophysical part, concerning terrestrial magnetic field variations and atmospheric electric field variations as observed each morning at the « Val Joyeux » Observatory in Seine-et-Oise, a few kilometres from Versailles;

b) Astrophysical part, concerning the activity of sunpots, faculae and protuberances as observed each morning at the Observatory of Meudon, near Paris.

These Ursigrams have been emitted daily from FLE (Eifel Tower) Paris at 11 : 20 G. M. T. (2) on the frequency of 207.5 Kc/s or $\lambda = 1,445$ m.

The American section of the U. R. S. I., finding that these Eifel-Tower Ursigrams were frequently so faintly received as to be illegible in the United States, asked the French authorithies if it would be possible to have them repeated daily from the powerful French radio station Lafayette (FYL) near Bordeaux, which operates on the frequency of 15.7 Kc/s ($\lambda = 19,100$ m.). The French responded very courteously to this request, and after February 1st 1930, the FLE Ursigrams were repeated from FYL at 20 : 30 G. M. T. They were also repeated daily, at the same hour, from a short-wave station FLJ (Issy-les-Moulineaux) near Paris on the frequency 9225 Kc/s ($\lambda = 32.5$ m.).

Since January 1st 1931, the daily French Ursigram service has been maintened from the following stations :

Station.	Location.	Frequency Kc/s.	Wave Length m.	S. M. T.
FYL	Lafayette, Bordeaux	15.7	19100	20 : 30
FYB	Paris-Pontoise (near Paris).	10581	28.35	20 : 30

Ursigram transmissions from FLJ and FLE have been suspended.

The following is a sample French Ursigram from FYL, as recorded by a U. S. Navy receiving station for January 14th 1931, and as repeated by Science Service (Research Announcement No. 36 of January 20th 1931).

> *Bulletin astrophysique* du 14 janvier. — Activité tache nulle, activité faculaire faible. — Activité protubérance faible.
>
> *Bulletin géophysique* du 14 janvier. — L'activité magnétique est calme, le champ électrique est très agité. — Le gradient du potentiel est très variable.

American Ursigram.

Commencing on August 1st 1930, a daily Ursigram service was opened from the U. S. Navy radio station NAA Washington D. C. It has been continued every day since that date, under the auspices of « Science Service », 21st and B Streets (National Academy of Science Building) Washington D. C. Data for the Ursigram are contributed by the U. S. Coast and Geodetic Survey (Magnetic), the Mt. Wilson Observatory and U. S. Naval Observatory (sunspots), the Smithsonian Institution Astrophysical Observatory (solar constant) and other scientific bodies. These data are transmitted daily to « Science Service » Washington, over the U. S. Army radio net. « Science Service » assembles them and delivers them to the U. S. Navy Department, whence they are emitted by NAA on schedule time.

From August 1st 1930 to December 31st 1930, the American Ursigram was transmitted from NAA on a frequency of 16,060 Kc/s ($\lambda = 18.68$ m.) at 21 : 00 G. M. T. as an addition to a weather message directed at FYL (Lafayette station near Bordeaux). Since Januay 1st 1931, the transmission has been at 22 : 00 G. M. T. (5 p. m. Eastern Standard Time) on two frequencies simultaneously; namely, 12,045 Kc/s and 4,015 Kc/s ($\lambda = 24.9$ m. and $\lambda = 74.7$ m.).

Example of an American Ursigram.

The following example is given by « Science Service » (1) as an example of an Ursigram emitted daily by NAA :

URSI SOL 79333 MAG 1535X 08407
SUN 10314 SCIENSERVC.

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(1) For particulars concerning the French Ursigram the writer is indebted to the office of General Ferrié and the Office National Météorologique.

(2) G. M. T. means Greenwich Mean Civil Time.

(1) American Ursigram Code explained in *Science Service* Research Announcement, No. 6, of July 24th 1930.

The Ursigram contains 9 groups of signals. The first (URSI) is the distinguishing group at the beginning of the message. The last is the slightly abbreviated signature of Science Service, this name « Scienservc » is also the cable address of « Science Service » Washington D. C.

There are three sets of data in this message :

1. *The Solar Thermal Constant* for the day (SOL 79333) as reported by the Astrophysical Observatory of the Smithsonian Institution from the average values of its observers at Montezuma Station, Chile.

2. *The Terrestrial Magnetic Data* for the day (MAG 1535X 08407) as supplied by the U. S. Coast and Geodetic Survey, from its observatory at Tucson Arizona (Lat. 38°14.8′ N., Long. 110°50.1′ W.), for the period of 24 hours preceding 14 hours G. M. T. of the Greenwich and local day of the week as given by the first letter of the group 1535X.

3. *The Sunspot Data* for the day (SUN 10314), as furnished by the Mount Wilson Observatory, of the Carnegie Institution of Washington, at Pasadena California from observations made at about 16 hours G. M. T. (7 a. m. Pacific Standard Time) or as soon thereafter as weather permits.

Code used for SOL, the Solar constant.

One group of five figures (79333).

The first figure (7) indicates the day of the week reported for. In the example cited it was the seventh day or Saturday.

The second, third, and fourth figures (933) signify the decimal part of the constant in excess of unity. The thermal constant reported is thus 1.933 gram-calories per normal sq. cm. per minute received on the earth's surface, at the mean distance from the sun if the atmosphere was heat transparent or non-absorbent.

The fifth figure (3) indicates the nature of the observation reported, according to the following scale :

3 Satisfactory;
5 Not quite satisfactory;
7 Unsatisfactory.

The Sol group in the above example thus means Saturday, total intensity 1.933 gm. cal per sq. cm. per minute, satisfactory.

Code used for MAG, the terrestrial Magnetic Data.

One, two, or three five-number groups may be used. In the example, two (1535X 08407).

First group.

First figure (1) indicates the day of the week, here Sunday.

Second figure (5) indicates the magnetic character of the day according to the following scale :

3 Quiet day;
5 Day of moderate disturbance;
7 Greatly disturbed day.

In the case cited, the day was of moderate disturbance.

Third figure (3) indicates the nature of the disturbance according to the following schedule:

3 Day marked by a « bay disturbance » (¹) (lasting only an hour or so), i. e. a. departure from the normal curve in one direction only.
5 Day marked by rapid pulsations.
7 Day marked by long-period pulsations or oscillations.
9 Day marked by irregular oscillations.
X Signal for an unused or blank number.

In the example, the day had a bay disturbance.

Fourth figure (5) indicates that the second group (08407) to follow, gives the time of :

3 Beginning of disturbance.
5 End of disturbance.
7 Beginning of disturbance, with end given in third group.
X Not used.

In the example, the group to follow supplies the time of the end of the disturbance.

Fifth figure not being subject to use is replaced regularly by X.

Second group.

Second group (08407) gives Greenwich mean time of beginning or ending of disturbance, as indicated by the fourth figure of the preceding or first group. (If there is a beginning and end on the same day, a third group will give the time of ending.)

(¹) Resembling a bay indentation in an otherwise straight geographical coast line.

First and second figures (08). Hours, preceded by zero if less than ten.

Third and fourth figures (40). Minutes, preceded by zero if less than ten.

Fifth figure (7). Tenths of minutes, in the case of a sudden commencement of a disturbance. Other times will be given to whole minute only, and X will replace the fifth figure. In the example, 08407 means that the disturbance time was 08 : 40.7 G. M. T. and this was the *end* of the disturbance according to the fourth figure (5) of the preceding group.

Code used for SUN, the Sunspot Data.

This is a single group of five figures (10314).

The first figure (1) indicates the day of the week, in this case Sunday.

The second and third figures (03) indicate the total number of groups of sunspots, preceded by zero if less than ten. In this case, there were three groups of spots.

Fourth and fifth figures (14) indicate total number of spots, preceded by zero if less than ten. In this case there were 14 spots in all.

Proposed Additions to the American Ursigram.

It is proposed to add certain new cosmic data to the daily American Ursigram, as soon as the arrangements now being made for the observation of the data and their regular transmission to « Science Service » shall have been completed. These new data relate (A) to Aurora Borealis and (B) to measurements of the apparent height of the ionised layer or layers in the upper atmosphere.

A. — Aurora Borealis Observations.

The Alaska Agricultural College and School of Mines is situated at College, Alaska, in approximate Lat. 64.8° N., and Long. 147.7° W., about 8 Km. North of Fairbanks Alaska.

This college is thus within 2° of the Arctic Circle; but it can ordinarily be reached, by regular transportation, at any time of year. The department of Physics of this College is equipped for the observation of auroras, for a limited period, under a grant from the Rockfeller Foundation. Such observations are more effective during winter months.

The following code has been prepared in advance for the Ursigram transmission of auroral observations from College Alaska, subject to such modifications as experience may render necessary.

Example of a Bulletin on auroral observation AUR included in an Ursigram.

AUR 15082, 25355, 57817. This consists of the index three-letter group AUR to show that the next group or groups relate to Auroras. There follow in this case 3 groups of 5 numbers each.

FIRST GROUP.

First figure (1) shows the day of the week as in all the American Ursigram Bulletins. In the case considered, this was Sunday.

Second figure (5) indicates the auroral character of the day according to the following scale :

0 No aurora observed;
1 Faint;
3 Moderate;
5 Strong;
7 Brillant;
9 No observations, or no observations posble on account of cloudiness.

In this case, there was a strong aurora.

Third and fourth figures (08) indicate the number of hours in which aurora was present, preceded by zero if less than 10. In this case it was present for eight hours.

Fifth figure (2) indicates cloudiness on the scale 0, 1, 2 ... 9, X; 0 indicates no clouds, and X a completely overcast sky. In this case there was slight cloudiness.

SECOND GROUP.

First figure (2) indicates the form of aurora :

0 Homogeneous quiet arcs	without	ray-structure.
1 Homogeneous bands	—	—
2 Pulsating arcs	—	—
3 Diffuse luminous surface	—	—
4 Pulsating surfaces	—	—
5 Feeble glow	—	—
6 Varied forms	—	—
7 Flaming aurora	—	—
8 Varied and flaming	—	—

In this case there were pulsating arcs without rays.

Second figure (5) indicates the form of aurora:

0 Arcs	with	ray structure.
1 Bands	—	—
2 Draperies	—	—
3 Rays	—	—
4 Corona	—	—
5 Varied forms	—	—
6 Flaming aurora	—	—
7 Varied and flaming	—	—

Third figure (3) indicates the maximum area of sky covered by aurora on a scale 1-5, 5 representing a sky completely covered by aurora. In this case, the sky was three-fifths covered at maximum display.

Fourth and fifth figures (55) indicate average altitude of aurora in degrees. In this case it was 55°.

THIRD GROUP.

First, second and third figures (578) indicate general position of aurora, combinations being reckoned for included position in clockwise direction : 0 South, 1 S. W., 2 W., 3 N. W., 4 N., 5 N. E., 6 E., 7 S. E., 8 Zenith, 9 Whole sky. In this case, the display was from north east to south east to zenith.

Fourth and fifth figures (17) indicate the (G. M. T.) Greenwich Mean Time (preceded by zero if less than 10), of the observed greatest display, in the 24 hours preceding the time of filing report. In this case, the maximum was at 17 hours G. M. T. The regular hour of daily filing is not yet announced.

B. — Measurements of apparent height of the Ionised Layer, at a definite site, time and frequency.

A code for embodying these measurements has been drafted and submitted to the British National U. R. S. I. Committee for consideration, since it is hoped that the British Committee will be able to employ the same code for observations in Great Britain. The matter is still under consideration; but may be decided before this report is printed, in which case it may be included.

Collection and Distribution of American Ursigrams.

Science Service compiles a weekly mimeographed sheet of American Ursigrams in coded form, as issued during the preceding calendar week from NAA, and also the French Ursigrams received from FYL during the same period. Science Service distributes a limited number of these mimeographed weekly sheets by mail, on request. The sheet issued on February 10th, covering Ursigrams sent and received during the week February 1st to 7th is numbered 39.

Publication of American Ursigrams.

Commencing with the December 1930 number, *Terrestrial Magnetism and Atmospheric Electricity*, an International Quarterly Journal (conducted by Louis A. Bauer and J. A. Fleming, published under the auspices of the Johns Hopkins Press, Baltimore, Maryland, U. S. A., London Agents, E. G. Allen & Son, Ltd., 14 Grape Street, London W. C. 2) prints a quarterly Table of the contents of American Ursigrams (MAG, SUN and SOL) in decoded form, from material collected at the Department of Terrestrial Magnetism, Carnegie Institute of Washington, Washington, D. C. The first publication appears on pages 252 and 253 of No. 4, Volume 35 (Dec. 1930) covering the quarter 1st August-31st October 1930. A preliminary announcement of the code to be employed appeared on pages 184-185 of the same quarterly Journal in No. 3, Vol. 35 for Sept. 1930.

Proposed British Ursigram.

A weekly Ursigram from the British Committee has been under contemplation, covering measurements of the apparent height of the ionised layer, and apparent positions of sources of atmospheric electrical disturbances, to be emitted in code weekly from French Ursigram radio transmitting stations. It is hoped that this program may be put into operation as soon as arrangements for making, collecting, and transmitting the data shall have been completed.

It seemed desirable to the Liaison Committee that cosmic data collected in Europe should be emitted if possible through the French Ursigram stations only, because, if each country in Europe should emit Ursigrams through its own local radio stations, the difficulty of receiving, recording and collecting the data would be much greater than if all countries communicated their data to be emitted once each day from the French station or stations.

In a similar manner, cosmic data observed in either North or South America should be emitted from a single American radio station or group of associated stations. At present the U. S. Navy station of NAA near Washington D. C. performs that function. It is hoped to include later, data from Carnegie Institution Observatories at Huancayo Peru, and perhaps Watheroo, Western Australia.

It would be desirable at a latter period to have a radio station in Eastern Asia emitting Ursigrams for the Asiatic continent, in such a manner as to link up with cosmic data observation and emission in Europe and America. The growth and development of a scientific broadcasting service of this kind under the auspices of the U. R. S. I., can only be expected to occur as each element in the system justifies its existence and reveals its utility in providing speedy information of a kind that is serviceable to the science and art of radio transmission.

Meetings of the Liaison Commission.

An unofficial and informal meeting of the Liaison Commission was held in Stockholm on the 18th and 19th August 1930, in conjunction with and by kind permission of the General Meeting of the International Geodetical and Geophysical Union being held in Stockholm at that time. Several officers of the U. R. S. I. and a number of representatives of astronomy, geodesy and geophysics attended these informal meetings and joined in discussions on subjects of common interest to these various sciences. The status and development of the Ursigram service was outlined. The phenomena of delayed radio echoes were described by Dr. Stoerer, who gave an outline of his well-known theory for their explanation.

Several meetings of the U. S. National Committee on Liaison (Cooperation) have been held, in Washington D. C., at which the progress of Radio Liaison in general, and of Ursigram service in particular, have been discussed.

A. E. Kennelly,

Chairman of Commission IV.
21st February 1931.
Harvard University. Cambridge Mass. U. S. A.

ANNEXE II.

British National Committee.

THE PRESENT STATE OF LIAISON WORK IN GREAT-BRITAIN.

One of the original reasons for the appointment of Commission IV on Liaison, was to correlate the work of amateurs and to afford them such assistance as might be found practicable for experimental work of value.

At the meeting at Brussels in 1928 the British representatives stated that, in connection with various phenomena, attempts had been made in a definite and official manner to obtain assistance from amateurs, but, in general, the results had been very indefinite and had led to little useful result. Experience showed, however, that valuable results had been obtainable, if carefully chosen individuales were given definite duties with suitable apparatus. In this manner a number of amateur observers had recorded the strength of the reception from certain transmitting stations during the various phases of the total eclipse of the sun which occurred in England in 1927, and very useful and suggestive results had been obtained. The study of radio transmission, however, has entailed in an increasingly essential manner the use of quantitative measurements which are very seldom at the disposal of amateurs. It was therefore suggested that, as far as could be seen, efforts to obtain such assistance would not be likely to be repeated in England.

The type of liaison which could be more satisfactorily pursued would be the bringing to the notice of physicists and geophysicists and meteorologists those aspects of radio transmission which were of special interest to them, and which they might be expected to interpret in a manner useful for the study of the physics of radio transmission. The British National Committee has members on it closely associated with these subjects; and in addition the members of the British Radio Research Board and its various Committees include an additional number of persons of similar standing. Several of the members of the British National Committee are closely associated with the work of the Radio Research Board by being members of the Board or of its Committees.

The British National Committee has discussed at some length the subject of what they could usefully contribute to work and information of a liaison character; and they have had the advantage of a discussion of the subject with Prof^r^ Kennelly, Chairman of the International Liaison Commission. Prof^r^ Kennelly suggested the regular distribution of information of a cosmical physical character, which is or may be closely associated with the physics of radio transmission. He described the information and methods which had been recently adopted by the French and American organisations and gave details of the services which were being provided by « Science Service ». Among the phenomena which he suggested for consideration, and the study of which had been specially developed in England, were information as to the active upper (Kennelly-Heaviside) layer and the geographical position of important sources of atmospherics.

As to the method of distribution of information by radio, the British Committee came to the decision that in view of the difficulty of adding further information to the weather reports, etc., which were already as long as could be dealt with, and on account of administrative and other difficulties, they could not advise such information being distributed by radio from Great-Britain. They would, however, be glad to send any information to France, which they might decide that they could supply, if the French organisation would accept it and it to the information of a cosmical physical character which is transmitted by radio from various French stations. As a result of enquiries by the Liaison representative of the British National Committee, information has been received from France that they will be glad to afford such facilities, a decision which is very greatly appreciated.

Though information on the subjects named are those which the Committee considers they can most usefully supply to the common stock of information specially associated with radio physics, a defininite decision has not yet been possible, in view of the various administrative details which will have to be decided, including the collection and transmission of the information involved.

The National British Committee considers that the continuation of any provision of information by Great-Britain is to be regarded as being subject to the proviso that after a period of perhaps a year definite information should be submitted by the National Committees of other countries that the information has been of real value in assisting the study of geophysical and radio sciences.

Dr. E. H. Rayner,
7th March, 1931.

ANNEXE III.

Comité national français.

PROJET D'ORGANISATION D'ÉMISSIONS D'URSIGRAMMES FAITES PAR LES POSTES RADIOTÉLÉGRAPHIQUES FRANÇAIS SOUS LES AUSPICES DU COMITÉ FRANÇAIS DE RADIOTÉLÉGRAPHIE SCIENTIFIQUE.

Les émissions dont il s'agit sont destinées à remplacer les *Bulletins de géophysique* qui sont actuellement transmis en langage clair par les stations radiotélégraphiques de Bordeaux et de Pontoise, ainsi que par le poste radiotéléphonique de la Tour Eiffel.

La station de la Tour Eiffel (radiotéléphonie), ondes de 1,445 m. continuera à envoyer en langage clair le *Bulletin géophysique et astrophysique*.

Outre l'envoi de l'Ursigramme, les stations de Lafayette (radiotélégraphie, ondes de 18,900 m.)

et la station de Pontoise (radiotélégraphie, ondes de 28 m. 50) enverront journellement un groupe de lettres servant à des études sur la propagation.

Le programme de ces diverses émissions sera le suivant :

20 h. 06′ Greenwich, fin de l'émission des signaux horaires;

20 h. 10′ à 20 h. 15′, signaux pour l'étude de la propagation. Émission de la lettre *e* .. — .. et d'un groupe de lettres de contrôle;

20 h. 15′, Ursigramme.

Les Ursigrammes envoyés par les postes de Lafayette et de Pontoise comporteront :

1° Un *Bulletin météorologique* très condensé et établi par les soins de l'Office National Météorologique;

2° Un *Bulletin géophysique* donnant des renseignements sur l'état magnétique du globe et l'état électrique de l'atmosphère. Ce *Bulletin* sera établi par l'Institut de Physique du Globe de Paris d'après les relevés effectués à l'Observatoire du Val Joyeux (Seine-et-Oise);

3° Un *Bulletin astrophysique* relatif à l'activité solaire telle qu'elle se manifeste d'après l'observation des taches, des protubérances, des filaments (protubérances observées en projection) et des facules.

Ce *Bulletin* sera établi d'après les observations faites à l'Observatoire de Meudon.

Le schéma général des Ursigrammes sera le suivant :

URSI URSI URSI

B. A. R.

Texte du Bulletin Météorologique.

M. A. G.

Texte du Bulletin relatif à l'état magnétique.

E. L. C.

Texte du Bulletin relatif à l'électricité atmosphérique.

C. A. M.

Texte du Bulletin relatif aux phénomènes solaires.

Les projets de code relatifs à chacun des *Bulletins* sont donnés ci-après.

Il est prévu que ces messages seront complétés ultérieurement par :

a) Des renseignements relatifs à la localisation des centres de production des atmosphériques et à leur nature;

b) Par la valeur des hauteurs trouvées pour la couche Kennelly-Heaviside à une heure donnée pour une fréquence donnée;

c) Par des renseignements sur les aurores polaires observées.

Des démarches ont été effectuées auprès du Comité National Britannique pour qu'il veuille bien fournir les éléments nécesaires à la rédaction des messages (*a*) et (*b*), et auprès du Comité National Norvégien et du Prof^{r} Störmer pour obtenir les renseignements devant faire l'objet du message (*c*).

ANNEXE 1.

PROJET DE CODE POUR LE BULLETIN MÉTÉOROLOGIQUE QUOTIDIEN (B A R).

Ces messages seront des messages de situation générale sur la zone de l'hémisphère Nord, comprise entre 30 et 70° N., de 75° W. et 0°.

La forme symbolique des messages de situation sera la suivante :

Lignes isobares 1015 mb.	X LL 11	X LL 11
	X LL 11	X LL 11
Zones de basses pressions.	7 LL 11	QQQ
ou	7 LL 11	QQQQ
Zones de hautes pressions.	9 LL 11	QQQQ

A. — **Lignes isobares 1015 mb.**

Cette partie du message comprend une ou plusieurs séries de groupes de cinq chiffres. Chaque série indique une portion continue d'une ligne isobare 1015 mb. Elle a la forme X LL 11, X LL 11, X LL 11...

Le premier chiffre X des groupes de cinq chiffres est un simple numéro d'ordre de la ligne isobare qui est décrite en laissant toujours les *hautes pressions à droite*. Les quatre autres chiffres LL 11, donnent les coordonnées des divers points de la ligne (latitude et longitude).

Lorsqu'il est impossible de trouver une ligne 1015 mb. dans la zone précitée, on donnera les coordonnées d'une autre ligne isobare, dont la valeur sera indiquée en clair au début du message et de part et d'autre de laquelle les minima et maxima de pressions seront indiqués.

B. — **Zones de basses pressions.**

La forme de cette partie du message est la suivante :

7 LL 11 QQQ ou 7 LL 11 QQQQ

Le chiffre 7 est un chiffre indicatif, qui a lui seul signifie zone de basses pressions.

Les quatre chiffres suivants du premier groupe donnent les coordonnées de la zone de basses pressions (latitude et longitude).

Les trois ou quatre chiffres constituant le deuxième groupe QQQ ou QQQQ donnent la valeur du centre de basses pressions en millibars entiers.

Les séries 7 LL 11 QQQ (QQQQ) peuvent être répétées autant de fois qu'il y a de centres dépressionnaires à indiquer.

C. — **Zones de hautes pressions.**

L'aspect de la forme de cette partie de message est identique à la partie précédente :

9 LL 11 QQQQ

Le chiffre 9 est un chiffre indicatif, qui a lui seul signifie zone de hautes pressions.

Les quatre chiffres suivant du premier groupe donnent les coordonnées de cette zone.

Les quatre chiffres du deuxième groupe donnent la valeur en millibars entiers de la zone de hautes pressions.

15775-15065-14555-14352-14550-15240-
15730-16020-16210-16300.
23502-24000-24702-24310-23715-23020.
75352-985.
76030-1010.
73412-1005.
94530-1037.
94072-1038.

ANNEXE 2.

PROJET DE CODE POUR LE MESSAGE QUOTIDIEN RELATIF AUX PHÉNOMÈNES MAGNÉTIQUES ET ÉLECTRIQUES (M A G).

L'Ursigramme magnétique comprend deux groupes de cinq chiffres désignés symboliquement par :

a b c d e *f g h i j*.

a = jour de la semaine . . . . 1 Dimanche, 2 Lundi, 3 Mardi, 4 Mercredi, 5 Jeudi, 6 Vendredi, 7 Samedi.

b = caractère du jour d'après l'ensemble des 3 composantes.
- 0 calme absolu.
- 1 presque calme.
- 2 un peu agité.
- 3 agité.
- 4 très agité.
- 5 perturbation modérée.
- 6 forte perturbation.
- 7 très forte perturbation.
- 9 pas d'observation faite.

c = détails remarqués sur les courbes d'enregistrement.

1, 2, 3, 4, concernent la déclinaison (ou Y).
5, 6, 7, 8, concernent la composante horizontale (ou X).

On choisira la plus caractéristique des deux composantes.

1 ou 5 = encoche unique (fig. 1).
2 ou 6 = pulsations rapides (fig. 2).
3 ou 7 = longues périodes ou oscillations (fig. 3).

4 ou 8 = oscillations irrégulières (fig. 4).
0 = journée ne présentant pas ces caractères.

9 = pas d'observation faite.

Nota. — Lorsque plusieurs phénomènes se présentent dans la même journée : encoche, pulsations rapides, etc., on indiquera seulement celui qui paraîtra le plus important.

d e = heures.

f g = minutes.
(Heure du début du phénomène.)

Remarques : Dans le cas d'un phénomène ayant débuté en des jours précédents, on notera : *d* = 8, *e* = 8, *f* = 8, *g* = 8. S'il n'y a pas d'observation faite, on notera : *d* = 9, *e* = 9, *f* = 9, *g* = 9.

La notation 9 9 9 9 s'emploiera également dans le cas où les courbes ne manifestent pas de perturbation et de manière plus générale, quand on ne peut pas déterminer de début suffisamment net.

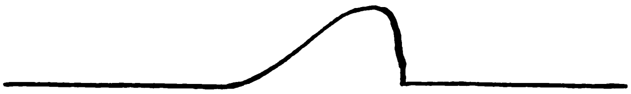

FIG. 1.

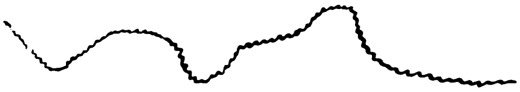

FIG. 2.

h = netteté du début . . . .

1 = début brusque.
2 = début vague.
3 = pas de début visible (impossible d'indiquer d'heure).
8 = début ayant eu lieu en des jours précédents.
9 = pas d'observation faite.

La notation 9 s'emploiera aussi dans le cas où les courbes ne manifestent pas de perturbation.

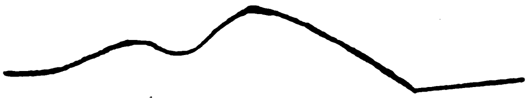

FIG. 3.

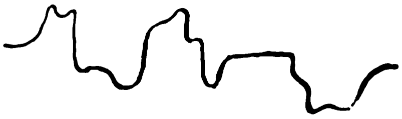

FIG. 4.

i j = heure approximative de la fin présumée du phénomène (comptée de 0 à 24 heures).

Exemples : i j = 05 = fin vers 5 heures;
i j = 88 quand le phénomène ne semble pas encore terminé dans la journée envisagée;
i j = 99 = pas de détermination faite.

99 s'emploiera également dans le cas où les courbes ne manifestent pas de perturbation et dans le cas où la fin est imprécise.

EXEMPLE.

Observations magnétiques du mardi 24 février 1931.

MAC
35204 14188

Traduction. — Mardi, perturbations modérées, pulsations rapides sur la courbe de déclinaison. Aucune particularité sur la composante horizontale. Début des pulsations, 4 h. 14. Début brusque.

Le phénomène n'est pas termnié le mardi.

ANNEXE 3.

(E L C)

L'URSIGRAMME D'ÉLECTRICITÉ ATMOSPHÉRIQUE COMPREND UN GROUPE DE 5 CHIFFRES, SOIT SYMBOLIQUEMENT : $a\ b_1\ b_2\ c_1\ c_2$.

a = jour de la semaine . . . . 1 Dimanche, 2 Lundi, 3 Mardi, 4 Mercredi, 5 Jeudi, 6 Vendredi, 7 Samedi.

b_1 = caractère du champ électrique entre 0 h. et 12 h.
- 1 presque calme.   9 pas d'observation faite.
- 2 un peu agité.
- 3 agité.
- 4 très agité (passages fréquents du positif au négatif).
- 5 inverti.

b_2 = caractère du champ électrique entre 12 h. et 24 h.
- 1 presque calme.   9 pas d'observation faite.
- 2 agité.
- 3 très agité.
- 4 tendance à l'inversion.
- 5 inverti.

c_1 = gradient de potentiel électrique entre 0 h. et 12 h.
- 1 faible.   9 pas d'observation faite.
- 2 moyen.
- 3 élevé.
- 4 très élevé.
- 5 variable.
- 6 très variable.

c_2 = gradient de potentiel électrique entre 12 h. et 24 h.
- 1 faible.   9 pas d'observation faite.
- 2 moyen.
- 3 élevé.
- 4 très élevé.
- 5 variable.
- 6 très variable.

EXEMPLE.

Observations d'électricité atmosphérique du samedi 5 juillet 1930.

ELC
74366

Samedi. — Champ électrique très agité de 0 à 12 heures avec changements répétés et rapides du sens du champ. Champ électrique agité de 12 à 24 heures.

Gradient de potentiel très variable de 0 à 12 heures et de 12 à 24 heures.

ANNEXE 4.

PROJET DE CODE POUR LE MESSAGE QUOTIDIEN RELATIF A L'ACTIVITÉ SOLAIRE (C A M).

Le message sera composé d'un groupe de cinq chiffres fournissant des indications générales sur les principaux caractères de l'activité de l'astre et, quand des taches ou des protubérances dépassant l'importance moyenne auront été observées, de groupes de cinq chiffres supplémentaires donnant des précisions sur les positions de ces objets. Éventuellement, il sera complété par la description, en langage clair, de phénomènes éruptifs exceptionnels.

Les renseignements qu'il contiendra seront déduits des observations faites avec le spectrohéliographe de l'Observatoire de Meudon.

1° Groupe d'indications générales.

Rang des chiffres dans chaque groupe.

1. Jour de la semaine, auquel les observations auront été faites :
    1 Dimanche.
    2 Lundi.
    3 Mardi.
    4 Mercredi.
    5 Jeudi.
    6 Vendredi.
    7 Samedi.

2. Activité évaluée d'après le nombre et l'importance des taches, dans l'échelle de 0 à 5 :
    0 Activité nulle.
    1 — faible.
    2 — moyenne.
    3 — assez forte.
    4 — forte.
    5 — très forte.

3, 4, 5. Activité évaluée, respectivement et dans la même échelle :
D'après le nombre et l'étendue des plages faculaires brillantes de calcium et d'hydrogène;
D'après le nombre et l'importance des protubérances observées en projection sur le disque (filaments);
D'après le nombre et l'importance des protubérances observées extérieurement au bord.

2° Groupes supplémentaires.

Leur premier chiffre servira d'indicatif de la nature des phénomènes dont les positions seront signalées :
3 pour les taches;
5 pour les protubérances observées en projection sur le disque;
7 pour les protubérances observées extérieurement au bord.

a) *Taches.*

2. Quadrant du disque dans lequel la tache (¹) est située :
    2 pour le quadrant Nord-Est.
    4 — — Sud-Est.
    6 — — Sud-Ouest.
    8 — — Nord-Ouest.

Les quadrants sont limités par le méridien central passant par les pôles du Soleil et par la perpendiculaire à ce méridien passant par le centre du disque.

3. Distance, exprimée en jours, de la tache au méridien central.

4, 5. Comme 2 et 3, respectivement.

Si le nombre de taches à signaler dépasse deux, de nouveaux groupes de cinq chiffres commençant par 3 et disposés de la même façon que ci-dessus, seront ajoutés. Il est peu probable, toutefois, que l'on ait jamais à donner les positions de plus de quatre taches à la fois.

Quand les taches signalées seront en nombre impair, les 4ᵉ et 5ᵉ chiffres du dernier groupe seront remplacés par des X.

b) *Protubérances observées en projection sur le disque* (*Filaments*).

Rang des chiffres dans chaque groupe.

2. Quadrant du disque où se trouve le milieu du filament (pour la notation, voir paragraphe *a*).

3. Distance, exprimée en jours, du milieu du filament au méridien central.

4. Indication sur la position du filament en latitude (¹) :
    4 Filament de basse ou de moyenne latitude.
    6 Filament polaire.

5. Chiffre non employé et remplacé par X.

Il sera transmis autant de groupes de cinq chiffres commençant par 5 qu'il y aura de filaments à signaler. Leur nombre ne dépassera probablement jamais trois.

c) *Protubérances observées extérieurement au bord.*

2. Quadrant où se trouve le milieu de la protubérance (pour la notation, voir paragraphe *a*).

3. Indication sur la position de la protubérance en latitude (comme dans le paragraphe *b*).

4, 5. Comme 2 et 3, respectivement.

Si le nombre de protubérances à signaler dépasse deux, de nouveaux groupes de cinq chiffres commençant par 7 et disposés de la même façon que ci-dessus, seront ajoutés; mais ce cas se présentera rarement.

(¹) Ou le centre du groupe, s'il s'agit de plusieurs taches voisines.

(¹) Cette indication n'est pas indispensable pour les taches, qui sont toujours confinées aux basses ou aux moyennes

Quand les protubérances signalées seront en nombre impair, les 4e et 5e chiffres du dernier groupe employé seront remplacés par des X.

EXEMPLES.

1. — Observations du dimanche 23 novembre 1930 :

Message : CAM 14312 34144 384XX

Traduction : Soleil : Dimanche. Activité d'après les taches, forte; d'après les plages faculaires de calcium et d'hydrogène, assez forte; d'après les filaments, faible; d'après les protubérances au bord, moyenne.

Trois taches ou groupes de taches importants sont à signaler :

Un dans le quadrant Sud-Est, à 1 jour du méridien central;

Un dans le quadrant Sud-Est, à 4 jours du méridien central;

Un dans le cadrant Nord-Ouest, à 4 jours du méridien central.

2. — Observations du jeudi 19 juillet 1928 :

Message : CAM 52440 362XX 5224X

Traduction : Soleil : Jeudi. Activité d'après les taches, moyenne : d'après les plages faculaires, forte; d'après les filaments, forte; d'après les protubérances au bord, nulle.

Un groupe de taches important est à signaler dans le quadrant Sud-Ouest, à 2 jours du méridien central.

Un filament important se trouve dans le quadrant Nord-Est, à 2 jours du méridien central, sa latitude est basse ou moyenne.

3. — Observations du jeudi 7 novembre 1929 :

Message : CAM 53434 34284 5804X 74684

Traduction : Soleil : Jeudi. Activité d'après les taches, assez forte; d'après les plages faculaires, forte; d'après les filaments, assez forte; d'après les protubérances au bord, forte. Deux taches ou groupes de taches importants sont à signaler :
Un dans le quadrant Sud-Est, à 2 jours du méridien central;

Un dans le quadrant Nord-Ouest, à 4 jours du méridien central.

Un filament important est à signaler dans le quadrant Nord-Ouest. Le milieu du filament est à moins de 0,5 jour du méridien central. Sa latitude est moyenne ou basse.

Deux protubérances importantes sont à signaler :

Une dans le quadrant Sud-Est (Protubérance polaire);

Une dans le quadrant Nord-Ouest (Protubérance de latitude basse ou moyenne.

COMMISSION V. — RADIOPHYSIQUE.

COMMISSION V. — RADIOPHYSICS.

INTRODUCTION.

La Commission de Radiophysique est composée des membres suivants :

The Commission of Radiophysics is composed of the following members :

Président :	M. le D^{r} B. VAN DER POL du Natuurkundig Laboratorium der N. V. Philip's Gloeilampenfabrieken.
Belgique :	M. F. DACOS, Chargé de Cours à l'Institut Montefiore; M. le Prof^{r} T. DE DONDER, Membre de l'Académie Royale de Belgique, Professeur à l'Université de Bruxelles; M. G. HOMES, Chargé de Cours à l'Université de Bruxelles et M. le Prof^{r} Ch. MANNEBACK de l'Université de Louvain.
États-Unis :	M. le Prof^{r} E. L. CHAFFEE of the Harvard University.
France :	M. le Prof^{r} E. BLOCH de la Sorbonne et M. LE CORBEILLER, Ingénieur en Chef des Télégraphes, du Laboratoire National de Radioélectricité.
Grande-Bretagne :	M. le D^{r} D. W. DYE of the National Physical Laboratory; M. le Colonel A. G. LEE of the General Post Office et M. le D^{r} R. A. WATSON WATT, Superintendant of the Radio Research Station.
Italie :	M. le Prof^{r} G. C. TRABACCHI et M. le Prof^{r} G. VANNI, Directeur Principal de l'Institut Radiotélégraphique Militaire.
Japon :	M. le Prof^{r} T. KUJIRAI of the Faculty of Engineering, Tokyo Imperial University; M. le D^{r} M. SO of the Tokyo Electric Company et M. le Prof^{r} H. YAGI of the Faculty of Engineering, Tohoku Imperial University.
Nouvelle-Zélande :	M. le D^{r} M. A. F. BARNETT of the Department of Scientific and Industrial Research.
Pays-Bas :	M. le D^{r} B. VAN DER POL.
Suisse :	M. le D^{r} J. LUGEON.

COMPTE RENDU DE LA SEANCE DU MERCREDI 3 JUIN

ACCOUNT OF MEETING OF WEDNESDAY, JUNE 3

La séance est ouverte à 16 heures sous la présidence de M. le Dr. B. van der Pol, Président de la Commission V.

Assistent à la séance : MM. le Prof^r^ Appleton, le Dr. Austin, le Commandant Bureau, le Dr. Le Corbeiller, le Capitaine Dorsimont, le Général Ferrié, le Prof^r^ Gorio, le Prof^r^ Jouaust, le Colonel Jullien, l'Ingénieur Latour, le R. P. Lejay, le Dr. Lugeon, le Prof^r^ R. Mesny, le Prof^r^ Nagaoka, le Prof^r^ Pedersen, le Dr. Rayner, le Dr. Smith-Rose, le Général Squier, le Prof^r^ Wagner et le Dr. Watson-Watt.

The *Chairman* proposes the following nominations :

Vice-Président : M. Mesny;
Rapporteur : M. le Dr. Le Corbeiller;
Rapporteur-Adjoint : le R. P. Lejay.

Ces propositions sont ratifiées par l'Assemblée.

La Commission entend ensuite un rapport de la Sous-Commission chargée d'étudier les règles qui doivent être appliquées dans la préparation et les discussions de l'Assemblée (¹), et propose d'étendre ces règles à l'U. R. S. I. toute entière.

Dr. Rayner says that those proposals would be acceptable to the British National Committee.

Ces propositions sont adoptées à l'unanimité.

Le *Général Ferrié* présente les excuses du Secrétaire-Général, M. R. B. Goldschmith, obligé de quitter la Conférence pour raison de santé.

The *Chairman* expresses the regrets and the good wishes of the Commission.

The *Chairman* then asks the Commission to nominate a member as delegate to the Polar Year Commission of the U. R. S. I.

Prof^r^ Appleton proposes M. van der Pol to be this delegate. It is due to him that the U. R. S. I. is in relation with the Polar Year Commission.

Dr. van der Pol accepts this function.

La réunion officieuse de la Commission tenue le matin a proposé de retenir trois sujets de discussion pour la prochaine Assemblée :

1° L'étude en laboratoire des gaz ionisés;
2° La nature de la radiation solaire et la composition de la haute atmosphère;
3° La génération des ondes de moins de 20 centimètres de longueur d'onde.

The *Chairman* puts forward as reporters to prepare the material :

For subject n° **1** : MM. Appleton and Gutton;
For subject n° **2** : MM. Chapman and Father Lejay.
For subject n° **3** : M. Wagner.

Ces propositions sont adoptées à l'unanimité.

Le *Dr. Wagner* demande l'autorisation de consulter M. Barkhausen et d'autres spécialistes.

The *Chairman* says that it was proposed an evening of the next meeting should be devoted to an exposition of the operational calculus in its foundations and its application to Radioelectricity.

Prof^r^ Appleton proposes that MM. van der Pol and Wagner be to undertake this.

Le *Prof^r^ Jouaust* expose les idées de M. Gutton (¹) sur les résonances dans les gaz ionisés, et sur ses expériences récentes où il a retrouvé la même fréquence avec des tubes de dimensions différentes et des densités d'ionisation semblables.

(¹) Annexe I, p. 96.

(¹) Annexe II, p. 98.

Prof^r Appleton says that with the help of M. Goodyear of King's College, London, he has repeated the experiments of M. Gutton and he confirms the results. He adds that the question at issue is the explanation to given of the experimental results. M. Pedersen has explained the experience of M. Gutton by Eccle's theory and has shown that the condenser of fig. **1** was equivalent to the three condensers placed as indicated on fig. **2**. He says that he has experimentally reproduced that arrangement as shown on fig. **3**. Varying the value of external capacities the resonance frequency was modified.

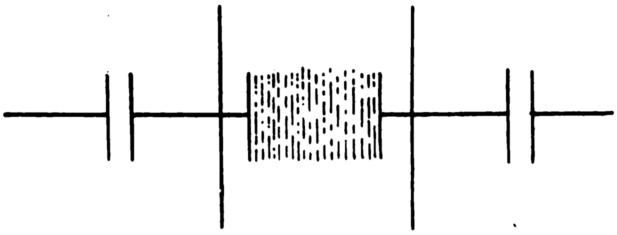

FIG. 1.

On the other hand, M. Gutton found the formula $N^{3/4}\lambda^2 = C^{te}$ where N is the number of ions per cm^3, N being measured by the current passing through the tube. But since these experiments, Langmuir has given a method of direct measurement for the number of ions and it is then found that the formula $N\lambda^2 = C^{te}$ is verified, according to Pedersen's theory.

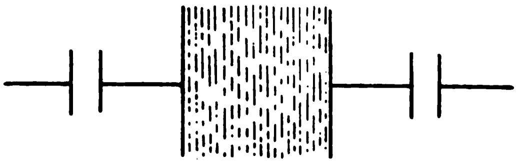

FIG. 2.

Le *Prof^r Jouaust* dit qu'il lui est difficile de se substituer à M. Gutton pour discuter cette question quoiqu'il en ait souvent parlé avec lui, mais il ne la connaît qu'imparfaitement. Il lui semble cependant que M. Gutton a répondu aux objections de Pedersen par des expériences qu'il a décrites dans les *Annales de Physique.*

Prof^r Nagaoka is not sure that electrons alone intervene and that ions could also have some influence.

Prof^r Appleton answers that the experiments he has made with a magnetic field acting make him believe that electrons alone are concerned.

Le *Prof^r Jouaust* ne voit pas comment s'expliqueraient les réflexions verticales autrement que par la théorie de M. Gutton. Il signale que les travaux de M. Namba au Japon montrent des polarisations elliptiques à la réception des signaux lointains, ce qui indique une réflexion du type métallique, conformément aux idées de M. Gutton.

Dr. van der Pol discusses the experiments he made in 1918 in view to finding dielectric constants smaller than one. In fact, at first he found numbers greater than one, but afterwards he met values less than one. He points out the important fact that the absence of homogeneity in the ionisation of gas might give too high value for the dielectric constant.

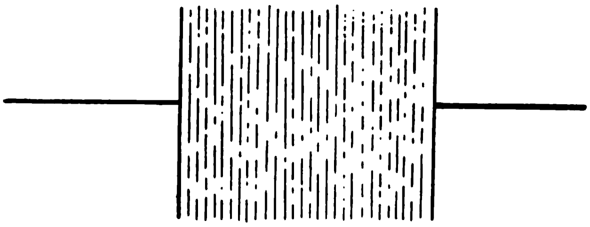

FIG. 3.

The *Chairman* then reads his report on the Brownian movement of electrical charges in conductors and on the general theory of reciprocity (1).

The *Chairman* opens then the discussion on the general theory of reciprocity in radio wave propagation. He asks if observations opposed to the theory could be put forward.

M. *L. Espenschied* says that in U. S. A. numerous experiments had been carried out in order to find whether the variations in reception in reciprocal radio-communications arose from the intervening medium or from the antenna system.

Some months ago variations were thought to have been found but later it was found that the measurements gave results identical to 1 or 2 decibels when the antennas were identical.

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(1) Annexe III, p. 100.

Those measurements were made with different arrangements on 10,000 Kc/s and 20 Kc/s.

The *Chairman* conclues from these accurate experiences that the influence of the terrestrial magnetic field could therefore be neglected in a first approximation not only on long waves but also on short waves.

Dr. Smith-Rose says he made experiments on this subject while studying night-time direction-finding at a distance of 80 miles. One of the stations was equipped with a rotating emitting frame and with a receiving frame, the other with a vertical antenna used for emission and reception.

The observed deviations were the same in both directions as far as could be determined in the conditions that the observation could not be stricly simultaneous; in fact the maxima were same.

M. *L. Espenschied* refers to observations made during transmission from North to South between U. S. A. and Chili. The rays directed Northward were deviated to the West and those directed Soutward to the East. The station of Buenos-Aires on the axis of the projection did not receive as well as the stations of Chili.

The *Chairman* remarks that this is not a fact opposed to the theory of reciprocity, it does not therefore appear that there is a single experimental fact against this theory.

Prof^r Nagaoka says that the « Mecanique Analytique » of Lagrange contains theorems on this subject, also the works of Helmotz, Boltzmann, etc.

The *Chairman* begs M. Nagaoka to give a list of references on this subject.

Ces références en addition de celles contenues dans le rapport de M. van der Pol (¹), sont les suivantes :

Lagrange-Mecanique analytique;
Helmoltz-Kleinste Wirking;
J. J. Thomson-Application of dynamics to Physics and Chemistry;
H. Hertz-Prinzipien der Mechanik;
Boltzmann-Prinzipien der Mechanik.

Référence additionnelle sur le mouvement Brownien :

Fowler-Statistical Mechanics.

La séance est levée à 18 heures.

(¹) Annexe III, p. 100.

ANNEXES.

I. — *Propositions relatives à la préparation et à l'organisation des travaux des Commissions.*

II. — *Étude de la Résonance dans les gaz ionisés.* — Prof^r GUTTON.

III. — *Report for Commission V.* — Dr. VAN DER POL.

ANNEXE I.

PROPOSITIONS RELATIVES A LA PRÉPARATION ET A L'ORGANISATION DES TRAVAUX DES COMMISSIONS.

L'Assemblée Générale actuelle semble devoir obtenir des résultats plus efficaces que les précédentes, et cela nous paraît dû à une meilleure conception du rôle de l'U. R. S. I. Ce rôle est le suivant :

D'une part, elle doit étudier les moyens d'action nécessaires pour la réalisation des travaux de nature internationale, et organiser cette action.

D'autre part, elle doit discuter les questions scientifiques et, dans la mesure du possible, profiter de ses Assemblées Générales pour atteindre ce but.

Il est incontestable que de semblables discus-

sions ne peuvent porter de fruits que si les points examinés ont été étudiés à loisir.

Pour régulariser sur ces bases l'organisation des futurs travaux, il serait avantageux d'établir, dès maintenant, quelques règles générales.

Les questions ressortissant du domaine de l'U. R. S. I. peuvent être classées en deux catégories :

A. — Questions générales en cours d'évolution et qui ne comportent pas, ou ne demandent pas de solution rapide. Tel est le cas, par exemple, de la constitution et de l'ionisation de la haute atmosphère, et des relations entre la propagation et l'activité solaire.

B. — Questions particulières pour lesquelles une solution rapide, ou au moins un avis sans longs délais, serait utile ou nécessaire. C'est le cas de la collaboration aux travaux de l'Année Polaire; ce peut être aussi le cas de l'examen de points de vue nettement opposés sur un sujet déterminé.

Enfin, le nombre croissant des travaux de toute espèce et leur discrimination dans de très nombreuses publications rendent difficiles la connaissance complète de certains sujets jouant un rôle essentiel dans la science radioélectrique; plusieurs membres de l'U. R. S. I. ont émis le désir de voir rassemblés par des spécialistes tous les éléments de documentation relatifs à ces questions, cette documentation étant accompagnée d'exposés critiques.

C'est en se guidant sur ces considérations que nous faisons les propositions suivantes :

A. — La préparation des questions à discuter dans une Assemblée Générale devra commencer officiellement au moins un an avant la date de cette assemblée. Le programme sera définitivement établi huit mois avant cette date, par entente entre les Comités Nationaux. Le Secrétariat Général prendra toutes dispositions utiles pour atteindre ce but en rappelant à l'ordre les Comités Nationaux qui apporteraient trop de retard dans leur correspondance et en leur fixant une date limite après laquelle on se passerait de leur avis.

B. — Un ou plusieurs rapporteurs qualifiés seront désignés pour chaque question et leurs rapports devront parvenir au Secrétariat Général trois mois avant l'Assemblée Générale. Ces rapports seront polycopiés et envoyés aux Comités Nationaux auxquels ils devront parvenir deux mois avant l'assemblée.

C. — Si d'autres questions se présentent au-delà des limites ci-dessus assignées, elles seront communiquées d'urgence aux présidents des commissions intéressées qui jugeront s'il est encore temps de les présenter à la prochaine Assemblée Générale et si cette présentation est justifiée par l'intérêt qu'elles présentent. Dans ce dernier cas ils nommeront un rapporteur. Le Secrétariat Général fera alors tout le possible pour que les rapports soient distribués avant l'ouverture de l'assemblée.

D. — Dans le cas où la nécessité d'une solution urgente empêcherait d'attendre la prochaine Assemblée Générale, les présidents des commissions intéressées nommeraient un rapporteur qui, par correspondance ou par contact direct avec les personnes les plus qualifiées, étudierait la question et ferait un rapport dans le plus bref délai. Ce rapport serait distribué dans les mêmes conditions que ci-dessus.

E. — Dans tous les cas, le Comité Exécutif veillera à ce que l'ensemble des questions à examiner dans une Assemblée Générale soit proportionnée au temps dont celle-ci disposera.

F. — Les questions qui auront été étudiées par les rapporteurs dans un but de documentation scientifique à l'usage des membres de l'U. R. S. I. ne seront pas présentées à l'Assemblée Générale pendant ses séances de travail. Elles feront l'objet de communications qui auront lieu de manière à ne pas empiéter sur le temps indispensable aux discussions.

G. — Au cas où des membres de l'U. R. S. I. désireraient présenter des sujets ne faisant pas partie du programme de l'Assemblée Générale, leurs communications devraient être soumises à l'avance au Comité Exécutif qui jugerait de leur opportunité et prendrait les mesures nécessaires pour que l'exposé de ces communcations ne nuise pas aux travaux de la session.

ANNEXE II.

LA RÉSONANCE DANS LES GAZ IONISÉS.

La théorie de Eccles étudie l'influence de l'ionisation sur la valeur apparente de l'indice de réfraction du gaz en imaginant que chacun des électrons se déplace dans le champ électromagnétique comme s'il était seul, et ne fait point intervenir de forces qui proviennent de l'action qu'exercent sur chacun des électrons les charges des autres particules électrisées.

En l'absence d'un champ électromagnétique et pour une distribution en moyenne régulière des charges ces actions ont une résultante nulle, mais il en est tout autrement dans un champ. Celui-ci, lors du passage des ondes n'est pas uniforme, il est impossible d'ailleurs de concevoir un champ électromagnétique d'intensité variable et uniforme. Les équations de Maxwell pour un champ uniforme donneraient des valeurs nulles pour les dérivées, par rapport au temps, des vecteurs électriques et magnétiques de sorte que le champ serait nécessairement d'intensité constante.

Il est ainsi indispensable d'admettre que l'intensité du champ varie d'un point à l'autre de l'espace. Les ions positifs de masse très supérieure aux électrons négatifs ont des déplacements beaucoup moindres, de sorte que les charges négatives se déplacent seules dans un réseau de charges positives à peu près immobiles.

Comme l'intensité du champ est nécessairement différente aux différents points, les déplacements des électrons le sont aussi et il en résulte nécessairement une répartition non régulière des charges électroniques. Dans ces conditions on ne peut plus admettre que les actions mutuelles entre les différentes charges particulaires se font équilibres et n'interviennent pas pour déterminer le mouvement de chacune d'entre elles. Il faut introduire dans l'équation du mouvement d'un électron d'autres forces que celle qui résulte du champ, le mouvement devient alors différent de celui que prévoit la théorie de Eccles et la constante diélectrique apparente du gaz a une autre expression que celle que l'on déduit de cette théorie.

En vue d'étudier expérimentalement cette constante diélectrique, H. Gutton (*Comptes-rendus*, 1927, *Annales de Physique*, 1930) a effectué des séries d'expériences de laboratoire dont les résultats s'expliquent dans tous leurs détails par l'existence de phénomènes de résonance entre la fréquence des oscillations du champ et une fréquence propre des oscillations électroniques. Cette dernière fréquence est due aux actions mutuelles des charges particulaires qui créent une force de rappel proportionnelle, en première approximation, au déplacement de l'électron.

Ces phénomènes de résonance sont d'autant plus marqués, ainsi que le montre l'expérience, que la pression est plus basse car l'amortissement des oscillations électroniques, dû à la présence des molécules gazeuses, est plus petit. Pour observer de grosses influences de ces résonances, il est par suite essentiel de faire les expériences à pression très réduite et aussi basse que dans les hautes couches atmosphériques.

D'autres expériences postérieures de H. Gutton (*Annales de Physique*, 1930), par des moyens très différents conduisent encore à l'idée de phénomènes de résonance importants.

Au cours de ces différents essais Tonks et Langmuir (*Phys. Rev.*, 1929) ont d'autre part trouvé par expérience des périodes propres d'oscillations des particules électrisées dans l'arc au mercure, et donné une théorie de ces oscillations basée sur la non uniformité du champ. Ils trouvent, comme les recherches expérimentale y conduisent, une force de rappel proportionnelle à l'écart dans le cas d'électrons déplacés par un champ électromagnétique.

Dans le cas d'un amortissement faible, l'équation du mouvement d'un électron doit donc être écrite non

$$m\frac{d^2x}{dt^2} = Fe\sin\omega t$$

mais

$$m\frac{d^2x}{dt^2} + ax = Fe\sin\omega t.$$

On trouve alors pour la constante diélectrique du gaz non plus

$$k = 1 - \frac{4\pi N e^2}{m\omega^2} = 1 - \frac{\Omega^2}{\omega^2}$$

en posant

$$\frac{4\pi N e^2}{m} = \Omega^2$$

mais

$$k = 1 - \frac{\Omega^2}{\omega^2 - \Omega^2}.$$

En désignant par Ω la pulsation propre $\sqrt{\frac{a}{m}}$ des oscillations électroniques, pulsation d'autant plus grande que les actions mutuelles entre particules sont plus intenses, c'est-à-dire que le gaz est plus ionisé. La théorie de Tonks et Langmuir donne pour Ω' une valeur égale à Ω. Celle-ci est d'autre part proportionnelle au nombre d'électrons par cm^3.

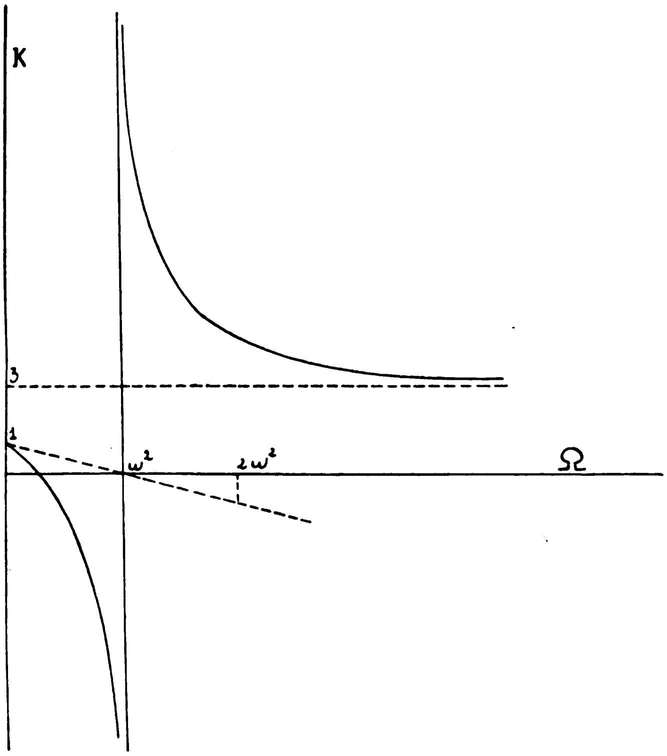

Fig. 1.

La courbe hyperbolique (fig. 1) qui représente la variation de k en fonction de Ω^2 ou de N^2 a alors une asymptote verticale pour $\omega^2 = \Omega^2$ qui correspond à la résonance. La courbe qui correspond à la théorie de Eccles est, au contraire, une ligne droite qui coupe l'axe des abscisses pour $\omega^2 = \Omega^2$.

Dans la théorie de la dispersion optique de Lorentz on trouve, comme il arrive ici, un indice infini qui correspond à une résonance électronique et à une bande d'absorption.

Il est important de remarquer que cette absorption ne correspond pas à une dissipation d'énergie en chaleur. L'énergie apportée par des radiations électromagnétiques à la surface de séparation du corps en résonance, sert à augmenter l'énergie cinétique des particules qui la rayonne à nouveau sous forme d'ondes réfléchies. Lorsque des ondes rencontrent un milieu en résonance électronique elles sont donc très parfaitement réfléchies. Cette réflexion est analogue à celle des rayons restants de Rubens sur un cristal, lorsque la longueur d'onde coïncide avec celle d'une bande d'absorption.

En appliquant ces résultats à la propagation des ondes radiotélégraphiques dans la haute atmosphère dont l'ionisation croît avec l'altitude jusqu'à une valeur maximum, on arrive aux conclusions suivantes :

I. — Les ondes sont réfléchies lorsqu'elles atteignent la couche en résonance et si la pression est faible sont peu absorbées avant de l'atteindre. Cette réflexion de la naure de la réflexion métallique peut dépolariser les ondes. Elle se fait sous toute incidence même voisine de la normale.

II. — La fréquence de résonance étant d'autant plus grande que l'ionisation est plus intense, les ondes les plus courtes sont réfléchies aux plus hautes altitudes. Seules les ondes ultra courtes qui ne rencontrent aucune couche en résonance peuvent quitter l'atmosphère terrestre.

III. — L'amortissement des oscillations électroniques étant dû à la présence des particules gazeuses, la réflexion est d'autant meilleure que la pression dans la couche en résonance est plus faible. Les ondes courtes seront donc mieux réfléchies que les ondes longues. Pour ces dernières la résonance se produisant dans des couches basses à pression élevée, les phénomènes qui provoquent la réflexion sont très amortis et cette dernière disparaît presque complètement.

Il est inutile d'imaginer l'existence d'une ou plusieurs couches ionisées à contours nets, tous les phénomènes observés s'expliquent du simple fait que l'ionisation varie d'une façon continue avec l'altitude.

L'ionisation nécessaire à la réflexion correspond à peu près à celle pour laquelle dans la théorie de Eccles la constante diélectrique s'annule, mais à la couche réfléchissante une théorie qui fait intervenir une résonance attribue, au contraire, une valeur très grande.

Ce dernier résultat coïncide avec celui des théories optiques, tandis que rien n'autorise à admettre qu'il y a réflexion lorsque l'indice est nul. Le passage par zéro d'une fonction n'implique en rien l'idée d'une discontinuité pouvant provoquer une réflexion.

C'est pour éviter cette contradiction que d'autres opinions ont été émises, la théorie de Eccles serait conservée et cependant une résonance interviendrait. Pour introduire cette résonance on fait le raisonnement suivant. La formule de Eccles indique que la constante diélectrique devient négative pour une ionisation suffisante. On imagine alors qu'un condensateur à constante diélectrique négative se comporte comme une self et que, par suite du fait de l'ionisation, chaque centimètre cube du gaz a une capacité et une self en parallèle. Il se produit alors des résonances pour une ionisation définie.

Cette manière de concevoir les phénomènes dont un gaz ionisé est le siège ne paraît pas raisonnable pour les raisons suivantes. Rien n'autorise à traiter un gaz comme un circuit oscillant, mais il paraît surtout injustifié de le faire. Lorsqu'en optique il a fallu expliquer les bandes d'absorption, Lorentz a imaginé une résonance électronique dans l'atome. On se trouve en radiotélégraphie en présence d'un milieu dispersif et absorbant dans lequel on étudie la propagation d'ondes. L'expérience montre que l'on trouve les résonances, qu'en optique on introduit comme le seul moyen d'explication et au lieu de profiter des faits d'expérience pour donner la même explication, on la néglige, au contraire, et on lui préfère une hypothèse que rien ne justifie.

Enfin, il semble naturel de chercher une théorie diélectrique des gaz ionisés à partir de leur structure particulaire et des lois de la mécanique, et de ne pas penser la trouver dans des assimilations problématiques d'un gaz ionisé à une self et une capacité.

H. Gutton.

ANNEXE III.

REPORT FOR COMMISSION IV.

In the scientific Radio literature of the last few years so many subjects have been treated, connected more or less with the physical mathematical bases underlying various radio phenomena, that it is practically impossible for one reviewer to give a complete account of the various, often very important advances of the last few years. It was therefore considered adequate to choose some subjects for discussion in the « Commission de Radiophysique », which are characterized by their very fundamental and general physical nature, so that they can be considered forming a subject for further scientific investigation in the near future. We suggest as such subjects :

1. The theory and experiments on the *Brownian* movement of electrical charges in conductors.
2. The « small shot » effect.
3. The general theories of reciprocity.

1. — The Brownian movement of electrical charges in conductors.

This effect, which in recent radio literature is variously referred to as « fluctuation noise » or « thermal noise », sets (together with the « small shot » effect) a limit to the amplitude of currents or P. D. 's, which can be amplified. In the telephone receivers, connected to the output of an amplifier, an irregular noise is heard, which has as its cause the spontaneous fluctuations of P. D. or current always present in any

conductor, their magnitude being determined by the temperature of the conductors.

The recent literature on the subject contains the following papers :

J. B. JOHNSON, *Thermal agitation of electricity in conductors.* (PHYS. REV. **32**, 97, 1928.)

H. NYQUIST, *Thermal agitation of electric charge in conductors.* (PHYS. REV. **32**, 110, 1928.)

F. B. LLEWELLYN, *Noise in vacuum tubes and attached circuits.* (PROC. I. R. E. **18**, 243, 1930.)

STUART BALLANTINE, *Fluctuation noise in radio receivers.* (PROC. I. R. E. **18**, 1377, 1930.)

In the paper by *Dr. Nyquist* a theoretical demonstration, based on general thermodynamical reasoning is given of the spontaneous voltage fluctuation, which is always present at the terminals of any linear network, which therefore obeys Ohm's law. It is shown, that these voltage fluctuations contain all frequencies. Calling $v^2(n)$ the square of the voltage components for the frequency region between n and $n + dn$, it is shown, that

$$v^2(n)\,dn = 4R(n)\,kT\,dn \qquad (1)$$

where $R(n)$ is the resistance component of the impedance (which equals the real part of the complex impedance) and k is *Boltzmann's* constant = $1{,}372 \times 10^{-23}$ Joules/degree, and T is the absolute temperature.

In the paper by *Dr. Johnson* measurements are described of these spontaneous voltage fluctuations and the results are compared with (1), so that *Boltzmann's* constant k could be determined and a fair agreement with the above given generally accepted value is obtained.

In the paper by *Dr. Ballantine* both the « shot » effect and the thermal agitation are considered and in connection with the last the noise is considered, when a carrier wave acts upon the high frequency side of a radio receiver, the latter containing a square law detector. For this derivation use is made of the *Rayleigh-Schuster* theorem, where an integral over the time is transformed in an integral over the frequencies. Results of measurements of « noise » of some radio receivers are also described.

In the paper by *Dr. Llewellyn* again both the « shot » effect and the « thermal noise » are discussed, the latter subject being again treated on the basis of *Nyquist's* equation (1). In the computation of the « thermal noise » originating on the plate side of the vacuum tube, the internal plate resistance of the tube is to be regarded as having the same temperature as the filament. *Dr. Llewellyn* further concludes, that with tubes properly designed to operate at temperature saturation, it is possible to reduce the noise on the plate side to such an extent, that the high impedance circuits employed on the grid side of the first tube of a high gain receiving system, contribute practically all of the noise by virtue of the thermal agitation phenomenon.

I may be allowed to add a few remaks in connection with the literature just described. With regard to the prediction of the above effect we find some references to a paper by *W. Schottky* : « Ueber spontane Stromschwankungen in verschiedenen elektrischen Leitern » (*Ann. der Phys.*, *57*, 541, 1918), who indeed forsaw the thermal agitation of electricity and who calculated its numerical value.

For a proper unterstanding of the phenomenon under question however it is advisible to compare the effect with the theory of the *Brownian* movement, the fundamental literature thereof being :

ALBERT EINSTEIN, *Zur Theorie der Brownschen Bewegung.* (ANN. DER PHYS. **19**, 371, 1906.)

M. VON SMOLUCHOWSKY, *Zur kinetischen Theorie der Brownschen Molekularbewegung und der Suspensionen.* (ANN. DER PHYS. **21**, 756, 1906.)

ALBERT EINSTEIN, *Ueber die Gültigkeitsgrenze des Satzes vom thermodynamischen Gleichgewicht und über die Mölichkeit einer neuen Bestimmung der Elementarquanta.* (ANN. DER PHYS. **22**, 569, 1907.)

LANGEVIN, *Comptes Rendus*, **146**, 530, 1908.

G. L. DE HAAS-LORENTZ, *Over de theorie van de Brownsche beweging en daarmede verwante verschijnselen.* Leiden 1912. — German translation : *Die Brownsche Bewegung.* Friedr. Vieweg & Sohn. (DIE WISSENSCHAFT, No. 52.)

H. A. LORENTZ, *Les théories statistiques en thermodynamique.* Leipzig & Berlin, Teubner, 1916.

It is interesting to remark, that in all publications just quoted the theory of the Brownian movement of electrical charges in conductors is treated and a numerical calculation of the effect to be expected is given. E. g. in *Einstein's* 1906 paper the following expression is given :

$$\overline{e^2} = \frac{2kTt}{r} \tag{2}$$

were t is the time and r the electrical resistance of a circuit and where e^2 is the mean square of a charge. About this formula *Einstein* remarks (1906) : « ...Diese Formel gibt an, wieviel Elektrizitët im Durchschnitt während der Zeit t durch irgendeinen Leiterquerschnitt geht... ».

Also in his 1907 paper *Einstein* shows, that the mean square voltage fluctuation v^2 at the terminals of a condenser of capacity C, due to the Brownian movement of electricity, is given by the expression :

$$\frac{1}{2}\,C\overline{v^2} = \frac{1}{2}\,kT. \tag{3}$$

In the book of *Mrs. G. L. de Haas-Lorentz* the Brownian movement of electricity is calculated in several circuits, e. g. it is shown, that in a closed circuit, consisting of a selfinductance L and a resistance r the spontaneous mean square current variation i^2 is given by

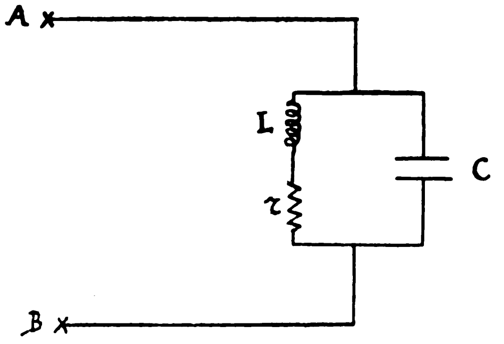

FIG. 1.

$$\frac{1}{2}\,L\overline{i^2} = \frac{1}{2}\,kT. \tag{4}$$

Also the case of two coupled L, r-circuits is considered, with the result

$$\frac{1}{2}\,L_1\overline{i_1^2} + M\,\overline{i_1 i_2} + \frac{1}{2}\,L_2\overline{i_2^2} = kT. \tag{5}$$

Finally for a L, C, r-circuit (see fig. 1) the mean square current and the mean square charge e^2 are shown to be :

$$\frac{1}{2}\,L\overline{i^2} = \frac{1}{2}\,\frac{\overline{e^2}}{C} = \frac{1}{2}\,kT. \tag{6}$$

Also in *Lorentz'* book (pages 97, 98, 99) a new derivation of the above is given.

In order to show the agreement of *Nyquist* formula (1) with e. g. *Einstein's* expression (3) consider the following circuit :

The real part of the impedance Z_{AB} is given by:

$$Re\,(Z_{AB}) = \frac{r}{\left(1 - \frac{\omega^2}{\omega_0^2}\right)^2 + \frac{\omega^2}{\omega_0^2}\cdot\frac{r^2}{L^2\omega}} \tag{7}$$

where $\omega_0^2 = \frac{1}{LC}$.

The mean square voltage $\overline{v^2}\,(\omega)$ as far as its components between the angular frequencies ω and $\omega + d\omega$ is concerned is therefore given by :

$$v^2\,(n)\,dn = \frac{4kT}{2\pi}\cdot\frac{r}{\left(1 - \frac{\omega^2}{\omega_0^2}\right)^2 + \frac{\omega^2}{\omega_0^2}\cdot\frac{r^2}{L^2\omega^2}}. \tag{8}$$

Integrating (8) over all frequencies between $\omega = 0$ and $\omega = \infty$ yields

$$\frac{1}{2}\,C\overline{v^2} = \frac{1}{2}\,kT$$

which agrees with *Einstein's* expression (3).

2. — The « small shot » effect.

As to the recent literature on the « shot » effect (wich was predicted by SCHOTTKY : *Ann. der Phys.*, *57*, 541, 1918) we mention :

A. W. HULL & N. H. WILLIAMS, *Determination of elementary charge from measurements of* « shot » *effect.* (PHYS. REV. **25**, 147, 1925.)

J. B. JOHNSON, *The Schottky effect in low frequency circuits.* (PHYS. REV. **26**, 71, 1925.)

T. C. FRY, *The theory of the Schroteffect.* (JRN. FRANKLIN INST. **199**, 203, 1925.)

W. SCHOTTKY, « Small shot » *effect and flicker effect.* (PHYS. REV. **28**, 74, 1926.)

N. H. WILLIAMS & H. B. VINCENT, *Determination of electronic charge from measurements of* « shot » *effect in aperiodic circuits.* (PHYS. REV. **28**, 1250, 1926.)

J. B. JOHNSON, *Thermal agitation of electricity in conductors.* (PHYS. REV. **32**, 97, 1928.)

STUART BALLANTINE, « Shot » effect in high frequency *circuits.* (JRN. FRANKLIN INST. **206**, 159, 1928.)

F. B. LLEWELLYN, *Noise in vacuum tubes and attached circuits.* (PROC. I. R. E. **18**, 243, 1930.)

STUART BALLATINE, *Fluctuation noise in radio receivers.* (PROC. I. R. E. **18**, 1377, 1930.)

Without going in details it can be said, that the above literature treats of the theory and experiments on the « shot » effect, which consists of a mean square voltage v^2, obtained over the terminals of a L, C, r-circuit, connected in the anode circuit of a thermionic tube, due to the fact, that the current through the tube is constituted by the movement of discrete electrons, whereby it is assumed, that every electron leaves the cathode statistically independent of the other electrons (see fig. **2**).

In its simplest form the theory leads to the following expression :

$$\frac{\overline{i^2}}{\bar{i}^2} = \frac{e}{2\overline{E}} \tag{9}$$

where $\overline{i^2}$ equals the mean square current through the capacty C, $\bar{i}$ is the mean current leaving the anode, e the charge of an electron and $\overline{E}$ equals the mean charge of the condenser, due to the mean potential drop $r\bar{i}$ of the direct current component over the resistance r.

An extension of this formula is given by *Dr. Ballantine's* paper for the case, where the finite time of transit between cathode and anode of the electrons is taken into account, which, as *Dr. Ballantine* shows, causes a reduction in the amount of the « shot » effect. In general it can be said, that theory and experiments agree reasonably well, though the change of « shot » effect due to the presence of space charge is worthy of further investigation, as is a further elucidation of the « Funkeleffekt », which introduces unexpected amplitudes at lower frequencies.

3. — The general theories of reciprocity.

In recent scientific radio literature we find some different forms given of the theory of reciprocity. In order to obtain a clear view of the different ways of expressing this theory, there follows an account of the different forms, in which this theory is expressed from its first enunciation by Helmholtz in 1866, *Handbuch der physiol. Optik*, *2*, 198, Ed. 1909 :

> « Ein Lichtstrahl gelange von dem Punkte A nach beliebig vielen Brechungen, Reflexionen, u. s. w. nach dem Punkte B. In A lege man durch seine Richtung zwei beliebige, aufeinander senkrechte Ebenen a_1 und a_2, nach welchen seine Schwingungen zerlegt gedacht werden. Zwei eben solche Ebenen b_1 und b_2 werden durch den Strahl in B gelegt. Alsdann lässt sich folgendes beweisen; Wenn die Quantität I nach der Ebene a_1 polarisierten Lichts von A in der Richtung des besprochenen Strahls ausgeht, und davon die Quantität K nach der Ebene b_1 polarisierten Lichts in B ankommt, so wird rückwärts, wenn die Quantität I nach b_1 polarisierten Lichts von B ausgeht, dieselbe Quantität K nach a_1 polarisierten Lichts in A ankommen. »

Helmholtz adds to this :

> « Sowie ich sehe, kann hierbei das Licht auf seinem Wege der einfachen und doppelten Brechung, Reflexion, Absorption, gewöhnlichen Dispersion und Diffraktion unteworfen sein, ohne dass das Gesetz seine Anwendbarkeit verliert, nur darf keine Aenderung seiner Brechbarkeit stattfinden, und es darf nicht durch Körper gehen, in denen der Magnetismus nach *Faradays* Entdeckung auf die Lage der Polarisationsebene einwirkt. »

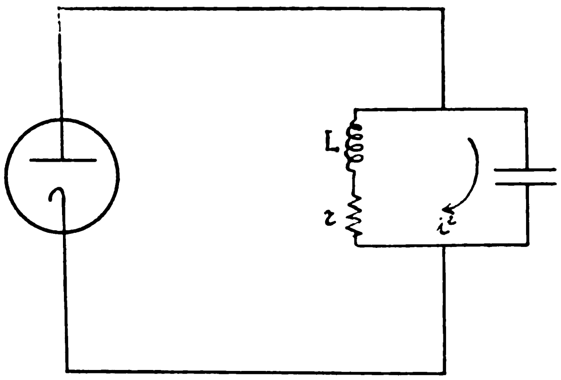

Fig. 2.

A theorem about currents and potentials of the frequency zero in a system of conductors is expressed by Maxwell in 1873 (*Treatise on Electricity and Magnetism*, I, art. 281) :

> « If an electromotive force E be introduced, acting in the conductor from A to B, and if this causes the potential at C to exceed that at D by P, then the same electromotive force introduced into the conductor from C to D will cause the potential at A to exceed that at B by the same quantity P. »

Rayleigh extended this in 1877 to periodic electromotive forces (*Theory of Sound*, I, par. 109) :

> « Let there be two circuits of insulated wire A and B, and in their neighbourhood any combination of wirecircuits or solid conductors in communication with condensers. A periodic electromotive force in the circuit A will give rise to the same current in B as would be excited in A if the electromotive force operated in B. »

In 1896 (*Verslag Kon. Ak. v. Wet.*, Dl. IV, p. 176, 1896), *Lorentz* proves the following theorem, which, as was the case in *Helmholtz's* theorem, relates to radiators and not only to quasi-stationary cases (as was the case in *Rayleigh's* theorem) :

> « If there exist in the points P and P′ simple light sources with the directions h and h_1 and with equal intensity and phase, than the electric current, which the first light source in P′ gives in the direction h', will always be equal to the electric current, which the second source produces in point P in the direction h''. »

In 1924, CARSON (*Bell. Syst. Techn. Jrn.*, *3*, 393, 1924), expresses the theorem of *Rayleigh* as follows :

> « Let a set of electromotive forces V_1', ... V_n' all of the same frequency, acting in the n branches of an invariable network, produce a current distribution I_1', ... I_n' and let a second set of electromotive forces V_1'', ... V_n'' of the same frequency produce a second current distribution I_1'', ... I_n''. Then
>
> $$\sum_{j=1}^{n} V_j' I_j'' = \sum_{j=1}^{n} V_j'' I_j'.$$

Further he derives the following theorem :

> « Let a distribution of impressed electric intensity $F' = F'(x, y, z)$ produce a corresponding distribution of current intensity $u' = u'(x, y, z)$ and let a second distribution of equi-periodic impressed electric intensity $F'' = F''(x, y, z)$ produce a second distribution of current intensity $u'' = u''(x, y, z)$ then
>
> $$\int (\mathbf{F}' . u'')\, dv = \int (\mathbf{F}'' . u')\, dv$$
>
> the volume integration being extended over all conducting and dielectric media. »

In 1926, *Sommerfeld* gives some theorems, relating to emitters (*ZS. f. hochfreq., Techn.*, *26*, 93, 1926); see also a correction on this former paper : « Das Reziprozitätstheorem der drahtlosen Telegraphie », Zenneck Festherft (*ZS. f. hochfreq. Techn.*, *37*, 167, 1931). *Sommerfeld* takes as his starting point the proof of *Lorentz*, however he does not accept any external (eingeprägte) electromotive forces, so that he obtains the equation

$$\operatorname{div}(\mathbf{H}_1 \times \mathbf{E}_2) = \operatorname{div}(\mathbf{H}_2 \times \mathbf{E}_1)$$

which is valid everywhere, where the divergence of the vector-product can be formed.

Sommerfeld concludes :

> « Die von der Antenne A_1 aus dem Felde E_2 empfangene Feldstärke ist nach Amplitude und Phase gleich der von der Antenne A_2 aus dem Felde E_1 empfangenen. »

As limitations of validity *Sommerfeld* gives a. o. no hysterisis, while an external magnetic field is excluded.

In 1927, *Pleyel* gives the following theorem for isotropic media (*Handl.* 68, *Ing. Vet. Akad.*):

> « The general reciprocal theorem consists therein that the linear equation system in operational from which combines the vectors I_1 and E_1 is conjugated with the system combining I_2 and E_2. »

In 1929, *Ballantine* gives the following theorem (*Proc. I. R. E.*, *17*, 929, 1929) :

> « If E'_0 and E''_0 are two independant distributions of impressed electric force which act on the total current (convention, conduction, polarization and displacement current in the ether) and c' and c'' represent the total current ($= \sigma + i\omega\varepsilon / 4\pi . [E + E_0]$)

resulting respectively from the action of E'_0 and E''_0; if all quantities vary as $e^{i\omega t}$, and if the properties of the medium ε, μ, σ are scalars and independant of the field vectors, then

$$\iiint (\mathbf{E}'_0 . c'' - \mathbf{E}''_0 . c')\, dv = \iint (\mathbf{E}' \times \mathbf{H}'' - \mathbf{E}'' \times \mathbf{H}')_n\, ds$$

were the surface integral extends over the boundary of the region of the volume integration. »

In 1930, *Carson* gives an extension of his reciprocity theorem (*Bell Syst. Techn. Jrn.*, *9*, 325, 1930), for the case $\mu \pm 1$ and further the following theorem of energies :

« If a transducer is terminated in its conjugate image impedances — the condition for maximum output and maximum transfer of power — the efficiency of transmission is the same in the two directions (¹). »

As stated already by *Helmholtz* in 1866, the reciprocity theorem is not valid when in the differential equations gyroscopic terms occur as was e. g. also remarked by *Profr Appleton* in connection with the propagation of waves through a medium, containing free electrons in the presence of a magnetic field. It would therefore be interesting to consider the question whether in actual propagation measurements cases have occurred, where it could be definitely concluded, that reciprocity in one of the forms given above did not apply.

Dr. B. VAN DER POL,
Chairman of Commission V.
May 1931.

(¹) *A critical review of the various forms of the reciprocity theorem will shortly be published* by Mr. J. W. ALEXANDER, *in the Tijdschrift v/h Ned. Radio Genootschap.*

SÉANCES PUBLIQUES. — PUBLIC MEETINGS

Il fut organisé trois séances publiques au cours desquelles les mémoires suivants furent lus et commentés par leurs auteurs.

Three public meetings were organized, during these the following papers were read and commented by their authors.

SÉANCE DU MARDI 2 JUIN. — MEETING OF TUESDAY, JUNE 2.

— L'exploration radioélectrique de l'atmosphère dans les régions polaires. — M. le Commandant Bureau.

— L'exploration indirecte de la haute atmosphère par les anomalies de propagation des parasites atmosphériques, et des ondes courtes au passage de l'obscurité à la lumière. — M. le Dr. Ing. Lugeon.

— A methode of measuring upper atmosphere ionization. — M. le Prof^{r} E. V. Appleton.

— The absorption of ionising radiation in the upper atmosphere near sunrise. — M. le Prof^{r} Chapman.

— Cathode ray direction finder in research on atmospherics. — M. le Dr. Watson-Watt.

SÉANCE DU MERCREDI 3 JUIN. — MEETING OF WEDNESDAY, JUNE 3.

— Wireless echoes. (Popular lecture.) — M. le Prof^{r} E. V. Appleton.

SÉANCE DU JEUDI 4 JUIN. — MEETING OF THURSDAY, JUNE 4.

— The theory of propagation over a flat earth. — M. le Dr. B. van der Pol.

— Sur la définition et sur la mesure des capacités internes dans un tube électronique. — M. le Major Chevalier Algeri Marino.

— Propagation of wireless waves. — M. le Prof^{r} Nagaoka.

— On the propagation of short waves. — M. le Capitaine M. Hattori.

— Frequency stabilisation of radio transmitters. — M. l'Ing. J. Kusunose.

— The modes of vibrations of quartz crystal plates. — M. le Dr. Dye.

— Measurements of power and efficiency of radio-transmitting apparatus. — MM. Gorio et Pession, mémoire lu par M. le Commandant Ing. T. Gorio.

Assemblée Générale du Samedi 6 Juin.

General Meeting of Saturday, June 6

La séance est ouverte à 16 heures, sous la présidence de M. le Général Ferrié.

Le *Président* ouvre la séance en annonçant que le Secrétaire Général, M. Goldschmidt a dû quitter Copenhague pour des raisons de santé, il exprime les regrets de l'Assemblée. M. Dorsimont attaché au Secrétariat, ayant été rappelé hier à Bruxelles, M. Mesny fera fonction de secrétaire.

Le *Président* se félicite ensuite de ce que M. Wagner ait bien voulu accepter l'invitation de l'Union, et il le remercie de la part importante qu'il a prise aux discussions. — Applaudissements.

On examine ensuite les résolutions proposées par les *Comités exécutif et financier, ces résolutions sont adoptées à l'unanimité* (¹).

Prof Appleton then presents the report of the Polar Year Sub-Commission (²). He asks that the name of Dr. Dellinger should be added to the list of members of this Sub-Commission.

Le rapport est adopté à l'unanimité et le nom de M. Dellinger est ajouté à la liste des membres de la Sous-Commission.

Dr. Rayner proposes to send to the General-Secretary a telegram expressing the wishes of the Assembly for a prompt recovery.

Cette proposition est adoptée aux applaudissements de l'Assemblée.

Les résolutions des Commissions I, II, III et IV sont ensuite adoptées à l'unanimité, avec quelques corrections de détail (³).

Le *Président* fait remarquer que les règles énoncées dans le rapport de la Commission V (¹) pour la préparation du travail des Assemblées Générales s'appliquent à toutes les Commissions, et qu'il y aurait lieu de les introduire dans un réglement intérieur que l'on pourra élaborer après les modifications prochaines des statuts.

Prof Appleton thinks that simultaneity of meetings of the C. C. I. R. and of the U. R. S. I. presents inconveniences as it prevents severals members of the Union from beeing present at every meeting. The assemblies of the two organisations ought to have at least a few days between. He also conveys an invitation from the British National Committee that the U.R.S.I. should hold its next General Assembly in London.

Le *Dr. Lugeon* fait connaître que l'Union de Géodésie et de Géophysique doit se réunir à Lisbonne en automne 1933; il y a lieu d'en tenir compte pour éviter des chevauchements regrettables.

Le *Président* fait remarquer que rien ne peut être décidé maintenant, et qu'on ne peut demander au Portugal d'inviter les trois organismes à la fois. Il propose de laisser au Comité Exécutif le soin de régler la question en tenant compte des avis précédemment exprimés.

Le *Président* annonce la clôture de l'Assemblée Générale, il estime que l'Union peut être fière du travail accompli et du programme si complet et si plein de promesses établi pour la première fois. Ces résultats sont certainement dûs à la proportion importante de savants de grande valeur qui ont été groupés à Copenhague.

Il remercie de leur travail bien organisé le

(¹) Annexes I et II, p. 108.
(²) Annexe III, p. 108.
(³) Annexe III, p. 110.

(¹) Commission V. Annexe I, p. 96.

Secrétariat Général de l'Union et le Secrétariat Danois. Il dit au Comité National Danois la profonde reconnaissance de l'Union pour l'accueil si cordial qu'elle a reçu.

Il adresse une particulière expression de gratitude au Profr Pedersen et l'assure de son admiration pour ses beaux travaux.

ANNEXES.

- I. — *Résolutions du Comité Exécutif.*
- II. — *Résolutions du Comité Financier.*
- III. — *Report of U. R. S. I. Sub-Commission on Radio-Work during the Polar Year 1932-1933.*
- IV. — *Resolutions of Commission I.*
- V. — *Résolutions de la Commission II.*
- VI. — *Resolutions of Commission III.*
- VII. — *Resolutions of Commission IV.*

ANNEXE I.

RÉSOLUTIONS DU COMITÉ EXÉCUTIF.

L'Assemblée Générale décide :

1° De maintenir dans leurs fonctions les membres actuels du Bureau et les présidents des Commissions;

2° Que l'Union fera tout le nécessaire pour obtenir l'adhésion de l'Allemagne et de l'U. R. S. S. aussitôt après que les nouveaux statuts du Conseil International des Recherches auront été adoptés à Bruxelles;

3° De ne pas demander l'admission de l'Union comme membre du C. C. I. R. afin de conserver sa pleine indépendance;

4° De faire savoir au C. C. I. R. que l'Union se tiendra, comme par le passé, à son entière disposition pour l'étude de tous les problèmes scientifiques qui pourraient lui être posés.

Ferrié,
Président.

ANNEXE II.

RÉSOLUTIONS DU COMITÉ FINANCIER.

L'Assemblée Générale approuve la gestion financière du Secrétaire Général pendant l'exercice écoulé, et lui donne mission de régler l'organisation du Secrétariat au mieux des intérêts de l'Union pendant l'exercice qui s'ouvre, tout en prenant toutes dispositions nécessaires pour éviter que les fonds actuellement disponibles ne soient entièrement dissipés avant l'élaboration des prochains statuts.

La publication des comptes rendus de l'Assemblée Générale sera limitée à un volume contenant les délibérations de l'Assemblée et ses discussions scientifiques, à l'exclusion des communications faites aux séances publiques.

R. Mesny,
Président

ANNEXE III.

REPORT OF U. R. S. I. SUB-COMMISSION ON RADIO-WORK DURING THE POLAR YEAR 1932/1933.

1. The Sub-Commission, consisting of the following members : Profr la Cour; Profr E. V. Appleton (President); Commandant R. Bureau; Dr. R. A. Watson-Watt; Dr. B. van der Pol, was asked to consider the advisability of making wireless observations during the Polar Year, and, if agreeing that such measurements were desirable, was entrusted with the task of formulating definite proposals concerning the nature of the work.

2. The Sub-Commission reports as follows :

a) It is strongly recommended that scientific radio observations should be made during the Polar Year.

b) The Sub-Commission recommends that measurements of Kennelly - Heaviside layer heights and ionization should be made during the Polar Year at stations as far North as possible, and suggests the following places :

Tromsö;
Scoresby Sound;
Thule;
Angmagssalik;
A station in Northern Canada;
A station in Alaska.

The Sub-Committee notes with satisfaction that the establishment of a station at Tromsö for making such observations has already been contemplated by the British National Committee, and that the Danish National Committee and the Dutch Committee for the Polar Year have similar projects for such work at Thule (Greenland) and Angmagssalik respectively.

c) The Committee recommends that all stations capable of making Kennelly-Heaviside height and ionization measurements, wherever these stations are situated, should carry out such measurements as regularly as possible during the Polar Year and in particular on the International Days of the Polar Year.

d) The Committee recommends that all stations capable of recording the intensity of atmospherics, wherever these stations are situated, should carry out such measurements as regularly as possible during the Polar Year and in particular on the International Days of the Polar Year. It is particularly desirable that the network of such stations should include stations situated as far north as possible.

e) For aural and other measurements of radio signal intensities the Committee recommends that a long wave station and a short wave station in Europe and a similar pair of stations in America should provide special transmissions. Transmisssions would be made at each hour during the International Days of the first order, long wave emissions taking place at the even hour and short wave emissions at odd hours G. M. T. The European stations would transmit from $0n00$ to $0n10$ and the American stations from $0n05$ and $0n15$ G. M. T. (n being an integer).

It is also recommended that observations should be made on the special Polar Year signals which are to be emitted daily by Pontoise-sur-Oise on 28.5 metres and by Bordeaux on 18,000 metres at 0810 and 2010 G. M. T. immediately after the time signals.

It is further recommended that observations be made on the signals emitted every Tuesday from Washington at from 1900 to 2100 G. M. T.

f) The Committee recommends that once per hour, whenever possible, estimates of atmospheric intensity and counts of the number of atmospherics heard per minute should be made on a wave-length of 6,000 metres or above, all observations at the same stations being made on the same wave-length throughout the Polar Year. In the case of stations equiped only for short wave reception the observations should be made on a wave-length as near to 60 metres as possible, such wave-lengths likewise being maintained throughout the Polar Year.

g) For the purpose of these recommendations the International Day is to be understood as beginning at 1600 G. M. T. Wednesday and ending 1600 M. G. T. Thursday.

3. The Committee asks that in the event of its proposal being confirmed by the U. R. S. I., it may be continued in office in order that it may carry out the detailed organization of the programme and the collection and preliminary reduction of the resulting data.

Dr. E. V. Appleton,
President.

ANNEXE IV.

RESOLUTIONS OF COMMISSION I.

1. To confirm the importance of continuing the researches, in all countries, on the absolute measurement of frequency, and to recommend the frequent interchange of the results of such measurements.

2. To recommend the utilisation of special transmissions of great constancy in connection with the above researches. For this purpose both unmodulated and modulated waves are considered valuable. The measurement of the resonant frequencies of piezo-electric quartz resonators, transported from country to country is also recommended.

3. To form an unofficial Sub-Committee of those specially concerned in transmissions and in the absolute measurement of frequency, in order to facilitate the arrangement of programmes and the collection and discussion of results of measurements.

4. It is desirable to make a comparative study of the various apparatus and methods used in the measurement of electric field intensity, in order to determined their merite and limitations. The British delegates offer to assist by the issue of a questionnaire and the preparation of a critical resumé of the information received.

Dr. Dye,
Président.

ANNEXE V.

RÉSOLUTIONS DE LA COMMISSION II.

L'Assemblée Générale décide :

1° Que les Comités Nationaux organiseront des mesures de la hauteur de la couche de Kennelly-Heaviside par la méthode de variation de fréquence ou par celle des échos.

Les résultats seront concentrés par M. Appleton qui dirigera l'ensemble des travaux.

2° Qu'une Commission permanente composée de MM. Appleton et Chapman, qui pourront d'adjoindre d'autres personnalités scientifiques, étudiera les conséquences des résultats fournis par ces mesures, en ce qui concerne les questions d'ordre radioélectrique, géophysique et astronomique que soulèvent les problèmes de la haute atmosphère.

3° Que le Comité National Français concentrera pendant une année tous les renseignements que pourront lui fournir les administrations et compagnies privées françaises sur les résultats du trafic, et qu'il dépouillera ces renseignements pour en tirer toutes conséquences utiles sur la propagation.

4° Qu'une Commission de cinq membres est constituée pour suivre la préparation des travaux de l'Année Polaire et préparer la collaboration éventuelle à ces travaux des différents Comités de l'Union. Cette Commission comprendra : MM. Appleton, Bureau, la Cour, van der Pol, Watson-Watt.

MM. Appleton et la Cour ont été désignés par la Commission II et les trois autres membres par les autres Commissions.

5° L'Assemblée Générale décide de demander à M. le Profr Wagner de faire des démarches pour obtenir l'émission par Nauen :

a) De signaux très brefs sur onde courte, signaux qui seraient enregistrés par le plus grand nombre de stations possible;

b) De signaux spéciaux destinés à l'observation des échos à long retard.

Si de telles émissions sont possibles, l'organisation des expériences sera confiée aux soins de la Sous-Commission constituée par MM. les Profrs E.-V. Appleton et S. Chapman.

R. Mesny,
Rapporteur.

ANNEXE VI.

RESOLUTIONS OF COMMISSION III.

1. To continue in office the Sub-Commission appointed at Brussels to design and distribute apparatus for atmospherics research, with the following (modified) membership, viz: MM. Austin, Snyder, Watson-Watt.

2. To nominate M. le Commandant Bureau as member of the Polar Year Sub-Commission.

3. To appoint a standing Sub-Commission of Commission III with the following membership, viz : MM. Appleton, Bureau, Lejay, Lugeon, Watson-Watt. To deal with the detailed execution of the projects contained in the following resolutions numbered 4 to 14 inclusive.

4. *a*) To establish a list of all stations already recording atmospherics, with their methods, and

b) A list of such stations whose installations has definitely been decided on, but not completed.

5. To scrutinise the electrical specification of the methods enumerated in the lists above mentioned, with a view to producing a practically attainable specification to facilitate comparison of data.

6. To further the use of universal frequencies for recording of atmospherics, the frequencies being 12 Kc/s, 50 Kc/s et 90 Kc/s.

7. To make provision for the rapid interchange of graphic data amongst participating stations, on a time scale of 6 cm/day.

8. To refer to the Polar Year Sub-Commission the proposal to make provision for special and exceptional observations, in addition to recording programmes, in particular the choice of « International Radio Days » related to the International Days of the Polar Year.

9. To ask the French National Committee to hand over to the British National Committee a Radiocinemographe indentical with those to be used at Paris, Algiers, Tunis, and Zi-Ka-Wei.

10. To ask the British National Committee to arrange for the operation of the instrument mentioned in resolution 9 along-side the British apparatus, over a considerable period.

11. To ask the British National Committee to arrange for the completest possible measurement of the characteristics of the instrument mentioned in resolution 9.

12. To arrange, in collaboration with the British National Committee, for the conduct of the simultaneous observations with photographie or visual cathode-ray direction-finders. In this connection it is noted with satisfaction that the Polish, French and American National Committees have undertaken to participate in such observations, and that the Danish Committee hopes to participate, the British observations being already in progress.

13. To consider the desirability and possibility of the radiation of synchronising signals for timing the observations mentioned in resolution 12, the French and American National Committees undertaking to give special consideration to this problem.

14. To arrange for the notification, with the least possible delay, of the occurrence of lightning flashes in various countries entering into special communication with the authorities of the « Pic du Midi » observatory and the Swiss authorities on this problem.

15. The Commission asks the General Assembly to give special confirmation to the resolutions :

a) That simultaneous measurements on the net changes of the earth's electric field, on the characteristics and interferent effects of atmospherics, and on the phenomena of visible lightning, should be effected in close interrelation in as many countries as possible.

b) That the Sub-Commission mentioned in resolution 3 be asked to draft detailed proposals to give effect to resolution 15*a* and

c) That the proposals resulting from resolutions 15*a* and 15*b* should be communicated officially by the U. R. S. I. to the International Meteorological Committee and to the International Union for Geodesy and Geophysics, with earnest request for their collaboration.

R. A. Watson-Watt,
Rapporteur.

ANNEXE VII.

RESOLUTIONS OF COMMISSION IV.

1. Thanks to Prof^r Kennelly for his report.

2. Request Prof^r Kennelly to transmit thanks to « Science Service ».

3. Approve the French Code for Ursigrams.

4. Approve supply of information concerning atmospherics by Great-Britain.

5. Approve supply of information concerning Kennelly-Heaviside layer by Great-Britain.

6. Request National Committees to facilitate cooperation of amateurs : for the study of short wave reception, for example.

7. Request National Committees to afford assistance on occasions of artificial explosions.

8. Nomination of M. Watson-Watt as member of the Committee of the Polar Year.

9. Request the President and Secretary to take any action considered desirable in connection with the Geodetic measurements of October 1933.

Dr. Rayner.

MARCEL HAYEZ, Imprimeur, 112, rue de Louvain, Bruxelles.

ANNEXE VIII.

RÉSOLUTIONS DE LA COMMISSION V.

1° Que les règles relatives à la préparation et à l'organisation des travaux des Commissions, contenus dans l'Annexe I, p. 96, soient suivies dans l'avenir en ce qui concerne la Commission V.

2° Que ces règles soient étendues à l'U. R. S. I. tout entière.

3° Que M. Balth. van der Pol représente la V^e^ Commission dans la Sous-Commission de l'Année Polaire de l'U. R. S. I.

4° Que des rapports sur les sujets suivants soient présentés à la prochaine Assemblée :

a) L'étude en laboratoire des gaz ionisés. Rapporteurs : MM. Appleton et Gutton;

b) La nature de la radiation solaire et la composition de la haute atmosphère. Rapporteurs : MM. Chapman et le R. P. Lejay;

c) La génération des ondes de moins de 20 centimètres de longueur d'onde. Rapporteur : M. K.-W. Wagner;

d) Les principes du calcul opérationnel (symbolique) et son application à la Radioélectricité. Rapporteurs : MM. van der Pol et Wagner.

5° De remercier M. Balth. van der Pol pour ses rapports sur le mouvement Brownien des charges électriques dans les conducteurs et sur les théorèmes de réciprocité.

Dr. BALTH. VAN DER POL,
Président.

Septembre 1934 Vol. IV September 1934

Union Radio Scientifique Internationale

International Scientific Radio Union

PALAIS DES ACADÉMIES — BRUXELLES

Secrétariat Général : 54, *Avenue des Arts, Bruxelles*

Recueil des Travaux de l'Assemblée Générale tenue à Londres en Septembre 1934
Proceedings of the General Assembly held in London in September 1934

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INTRODUCTION

La cinquième Assemblée Générale de l'U. R. S. I. tenue à Londres, en septembre 1934, comportait, outre l'Assemblée Générale proprement dite, des séances des cinq Commissions de l'Union.

Toutes ces réunions furent tenues dans les installations de la Royal Society, mises gracieusement à la disposition de l'U. R. S. I.

Les pays adhérents à l'Union étaient représentés par les personnalités dont les noms suivent :

Belgique : MM. P. BAUDOUX, le Dr. R. B. GOLDSCHMIDT et le Prof. C. MANNEBACK ;

Danemark : M. le Dr. D. B. la COUR ;

Etats-Unis d'Amérique : MM. L. A. BRIGGS, D. J. H. DELLINGER, L. ESPENSCHIED, R. A. HEISING, Dr. A. G. JENSEN, Prof. H. R. MIMNO, Prof. H. M. TURNER et W. P. WILSON ;

France : MM. le Commandant R. BUREAU, le Lieutenant de Vaisseau HABERT, le Prof. JOUAUST, le Prof. R. MESNY et l'Ing. PICAULT ;

Grande-Bretagne : MM. le Colonel A. S. ANGWIN, le Prof. E. V. APPLETON, N. ASHBRIDGE, F. S. BARTON, O. F. BROWN, Prof. S. CHAPMAN, Dr. W. H. ECCLES, T. L. ECKERSLEY, Prof. C. L. FORTESCUE, Prof. F. E. W. HACKETT, H. L. KIRKE, E. B. MOULLIN, Sir J. E. PETAVEL, J. A. RATCLIFFE, Dr. E. H. RAYNER, Dr. B. SCHONLAND, E. H. SHAUGNESSY, Dr. G. C. SIMPSON, Dr. R. L. SMITH-ROSE, L. B. TURNER, R. A. WATSON-WATT, Dr. A. B. WOOD ;

Italie : MM. le Dr. T. GORIO, le Lieutenant-Colonel A. MARINO, le Commandant C. MATTEINI et le Colonel L. SACCO ;

Japon : MM. I. KOGA, S. NAMBA, S. OKAMOTO et le Prof. H. YAGI ;

Nouvelle-Zélande : M. le Dr. F. W. G. WHITE ;

Pays-Bas : MM. le Prof. Dr. Jhr. ELIAS et le Dr. B. van der POL ;

Suède : MM. l'Ing. GEJER et le Dr. H. NORINDER ;

Suisse : M. le Dr. J. LUGEON.

M. le Prof. Dr. K. W. Wagner représentait les milieux scientifiques allemands.

Le *Secrétariat Général* était représenté par MM. le Dr. R. B. Goldschmidt, Secrétaire Général, et le Capitaine Dorsimont.

Madame le Dr. Mary Taylor, MM. L. H. B. Bainbridge-Bell, Barfield, F. M. Colebrook, F. E. Lutkin, Mac Petrie, Naismith, Page, le Dr. Smith-Rose, J. P. Vigoureux, Watson-Watt et A. F. Wilkins, ont rempli les fonctions de rapporteur aux cours des diverses réunions.

Séance Inaugurale du mardi 11 septembre 1934

Opening Session held on Tuesday, September 11, 1934

M. le Prof. J. C. Mac Lennan, Vice-Président de la Royal Society, ouvre la séance et prononce le discours suivant :

The President of the Royal Society, Sir Frederick Gowland Hopkins, has asked me to express his regret to you at being absent this afternoon. It was necessary for him to attend the meeting of the British Association in Aberdeen, and so he has asked me to take his place. On his behalf and on behalf of the Council of the Royal Society, the oldest scientific Society in Great Britain, I want to tell you how glad we are and what pleasure it has given us that you decided to hold your meetings this year in London. We extend to you the warmest of welcomes to the rooms of the Royal Society. Your London Committee and the officers of the Royal Society have given much thought to what the amenities of the place could provide, and if there is anything overlooked or anything that you would desire to add to your comfort all you have to do is to speak to Dr. Rayner and the matter will be attended to at once.

When I think of the object of this Congress, I, of course, have immediately in mind two great men. I recall Heaviside, that strange lonely scientist who did so much to present new ideas long before people were ready for them and that led to researches of the first order in later years. We also have in mind that charming scientist still living — Professor Kennelly — and we are very sorry that he is not with us to-day. Personally I regret it very much. I meet him at the meeting of the International Committee on Weights and Measures in Paris every year, and I know what useful help he can contribute on occasions of this kind. We regret that this absence is due to illness, and we hope that he will soon be well again. This matter will be referred to formally in a short time by other speakers.

We are proud, as Members and Fellows of the Royal Society, to include in our ranks one of your members, a great scientist, Dr. Eccles, one who has done much to verify and extend the ideas put forward years ago by the two scientists to which I have referred. I understand that the activities of the scientists who have taken part in the work of the Polar Year along the lines partially laid down by Professor Appleton and his associates and others, and which are going to be presented to us at this meeting, are of surpassing interest. It is amazing how much knowledge has been gained and is being gained by a study of the upper atmosphere through the use of radio waves. Personally, I have in mind studies of a cognate nature such as those initiated by Tisserac, du Bord, and followed up by others so energetically on the stratosphere and its constitution. I have in mind also the subject of the temperature of the upper atmosphere, as dealt with by Lindemann and Dobson through a study of the flight of meteors, and I recall the verification of their ideas by Whipple and others through their investigations on the reflection of sound waves. Then, again, perhaps I may be permitted to refer briefly to what we have learned from a study of the radiation emitted during Auroral displays.

We have in mind the names of such men as Stormer and others and what they have told us about the state of the oxygen and the nitrogen in the upper atmosphere, and the tremendous heights to which these two gases rise. We have in mind too the progress being made in studies carried out by the use of short radio waves, waves of the order of one metre and less. The penetrating power of these waves, and the biological effects they can produce, are all matters that make us realise that in the investigations in which they can be used we have a new field opening up of surpassing interest.

I perhaps may be permitted to say personally that I should like to see you extend your work so that we could get long trains of continuous radio waves a millimetre or so in length regularly and when we wanted them, and be able to study their polarization and their intensity and ascertain their wave length with exactness. With radio waves even shorter than one millimetre we should be able to obtain results of great interest scientifically.

These are only a few thoughts that have occurred to me, as I have not yet had an opportunity of studying the papers that are to be presented. I am only trying to imagine what is in them, and I think I have said enough to let you know I am going to look at them at least with expectancy. I am sure very interesting things will be found in them.

Now I have told you very heartily we welcome you. I hope I am going to have the opportunity of becoming more intimately acquainted with some of you later on, but in the meantime, as one of the Vice-Presidents of the Royal Society, I extend to you again a most hearty welcome.

I should like now to call upon your President Dr. Eccles to open your Session and take the Chair.

M. le Dr. W. H. Eccles, Vice-Président de l'U. R. S. I., prend la présidence et répond en ces termes à M. le Prof. Mac Lennan :

M. Vice-President of the Royal Society,
Ladies and Gentlemen,

My first duty is to join with Professor Mac Lennan in what he has said about the regrettable absence of Professor Kennely. This is not the moment to propose the sending to him of a message of sympathy, but I believe that will arise at the business meeting which follows this at 4 o'clock.

And then my second duty in taking the place of Professor Kennelly as acting President today is to thank the Vice-President of the Royal Society, the Council, and the Society as a whole, for so graciously placing at our disposal these beautiful rooms. They are exceedingly central, convenient, commodious, and have historical associations. Everyone coming here, I feel sure, will be proud to be in the very rooms that have witnessed the announcement of many great discoveries, and that have accommodated so many eminent men of all nationalities. We thank you, M. Vice-President, most cordially for the overwhelming hospitality of the Royal Society, and for the courteous words in which you have expressed your welcome.

The third task before me is one that I can do very indifferently as compared with Professor Kennelly, because he has probably a longer experience of wireless telegraphy than any one of us here. I remember him telling me that he remembered the announcement of the production by Hertz of electromagnetic waves, and their detection. He told me too about the shock it was to the scientific world to hear of these results. It seems to have been as great a surprise to our fathers as the announcement of the relativity principle was to us a generation later.

The only thing anticipating Hertz' discovery was the treatise of Maxwell and certain papers of his. The Maxwell equations were regarded as highly imaginative and theoretical, and scarcely likely to be realised in a short time, if at all. But after 1888 many prophets arose prophesying the imminent advent of practical wireless telegraphy by Hertzian waves, but the proposals were scarcely feasible until Branly showed that filings with two electrodes stuck into them proved to be a very sensitive detector of Hertzian waves.

Then I think we can say that the next great step was at the British Association's meeting at Oxford in 1894, exactly 40 years ago this week, when Oliver Lodge demonstrated the sending of Morse signals across a few hundred yards in an Oxford quadrangle. Lodge assembled a transmitter which consisted of a Hertz oscillator, a spark gap and induction coil, with a morse key and battery in the primary of the induction coil. By that means he could send messages by dots and dashes. He assembled also a receiving apparatus, a Hertz oscillator, tuned to resonate to the primary oscillator, just as Hertz had done. He took Branly's coherer and combined it with an ordinary telegraph relay, commonly called a Post Office relay, and a recorder. The minute currents from the coherer operated the relay and closed the contact, which permitted a heavy current to flow through the electromagnet of the recording apparatus, and this made ink marks on the moving tape. Thus messages in dots and dashes were transmitted for the first time. Although it was an experimental apparatus, not a practical apparatus, I think we may say that Lodge was the first of the wireless engineers. He took known principles and apparatus and combined them to produce a useful result. His receiver is the prototype of all modern receivers because it contains a resonant circuit, a detector, a relay or amplifier, and an indicating apparatus or printer. Those items appear even in the most modern receivers. Very quickly following Lodge, engineers in all countries made the sender bigger and more powerful, and made the receiver more sensitive, more robust, more practical. They did not alter the details very much but improved the various items. After 1894 not only engineers but physicists also were attracted into the subject, and it was out of this attraction of physicists, I think, that the U. R. S. I. has arisen.

Some of the problems appealing to physicists arose out of the difficulties that had stopped the progress of the engineers. Many of the results that the engineers achieved too, such as reception by crystal contact detectors, were mysterious and attracted investigators. But the efforts of the physicists of those days, from 1900 to 1910 say, were sporadic. Physicists studied portions of the subject that came to their notice by chance. As a fact, it was soon found that many of the big problems that confronted the engineers could not be touched without co-operation between widely separated workers. For instance, the study of atmospherics, is scarcely possible in an ordinary small country : we need a country as big as Russia to do it properly. And other problems, such as the propagation of waves, require co-operative efforts among workers in different countries. And so in 1912, on account of this feeling that wider co-operation was necessary, the British Association at the Dundee meeting appointed a Committee for an investigation of radio telegraphy phenomena. Oliver Lodge was Chairman and the Committee at first limited itself to work in the British Isles. Then in the course of six months it extended its work to America so as to get a contact with trans-Atlantic signals. Then it extended to shipping lines that went to different parts of the earth, so that after a year the Committee found that it wanted the whole globe for its province and perhaps a little more than that. With considerable aplomb or self-confidence the Committee began to arrange for observations on atmospherics and the propagation of waves, in practically very large country, the work culminating in an attempt to arrange for observers to take simultaneous observations of the effects of the eclipse of August 1914. By March, 1914, instructions for observations of the August eclipse were sent to outposts in practically every country and great attention was paid to the principal countries of Europe. The eclipse crossed from North to South through Scandinavia and was therefore very favourably placed for European observations. But the War arrived a few days before the eclipse and utterly smashed all the proposals for making wireless observations in Europe. There were a few observations made in America, Australia and Japan, but when they were analysed after the War it was found that they showed no trace of wireless propagation being affected by the eclipse so distant from them.

Quite independently of the work of the British Association Committee, another event very important to this Union occurred in 1914. This was the inspiration of Dr. Goldschmidt, who is with us to-day, to invite a number of radio men from several European countries to meet at Brussels and discuss long-distance radio transmission problems. They met at Easter, 1914, at Dr. Goldschmidt's Laeken Station near Brussels, and the principal discussions ranged over the possibilities of, and the proper apparatus for, communicating with the Belgian Congo. General Ferrié and Professor Abraham came from France, M. Duddel, Marchant, and myself from England, Professor Max Wien and Schmidt from Germany, Professor Benndorf from Austria; quite a number of people who had hitherto only known each other by name. We found from those meetings in Brussels that there are certain vivid advantages about oral communication as compared with written. That meeting alone was sufficient to convince me of the importance of having delegates from various countries actually meeting each other in order to discuss problems that cannot be discussed fully and frankly on paper.

After the War, the British Association Committee struggled to revive, and made an endeavour to track the effect of the eclipse of 1919 on wireless propagation, but it was soon found that it was not a suitable body for international work. Fortunately there was a movement started among purely scientific men to establish international unions in certain pure sciences. There was one designed for physics, another for chemistry and another for biology. Sir Arthur Schuster was Secretary, and as a member of the British Association Committee he knew all about its work and how it had started, and came to know of Dr. Goldschmidt's Committee. So he agreed readily that there ought to be a body for the study of radio science internationally.

Although he listened very sympathetically to those of us who wanted to make this Union a very important body, he believed, I think, at the time, that its proper place was as a Sub-Section of the Union for Physics. However, the nucleus of an independent Union for radio already existed in Dr. Goldschmidt's Committee, and that fact gave those of us who were anxious to obtain independence a strong claim to autonomous status. There were many consultations with Sir Arthur Schuster in Brussels, Paris and London, and in the result radio science was not subordinated to physics but given the same status as the great sciences. To outside observers it might seem strange when they read the list of the Unions that wireless has got this status in the scheme. It is not as if it were a border-line subject between physics and biology, say, incapable of being accommodated in either. It could easily have entered the Union for Physics, but there were good grounds for independence.

The first reason was that two organizations already existed and had done good work before the War — and the second reason was that the study of the propagation of wireless waves across long distances, makes the observational work intrinsically international to a much greater extent than the rest of physics.

I think also it must seem strange to outside observers when they read the list of the Unions that our science is the only one of them with a strong engineering flavour. There is no Union for the science of the internal combustion engine, for instance. There is no Union for ship-building science. In fact it is the only Union inside the select circle which embraces an applied science.

I think that it was a bold step to create this Union. It meant mixing two types of men — the engineer and the physicist — and this might promise disunion rather than union. This difficulty was discussed in full and is now seen to be more apparent than real. As a fact it solved itself by many radio engineers becoming physicists, and many physicists becoming engineers. These metamorphoses were greatly facilitated by the training the War had given to hundreds of men from physical and electrical engineering laboratories in every country who had entered wireless during the struggle. It is noteworthy that many of the physicists who entered wireless during the War never went back to pure physics. They permanently took the wrong turning.

It is largely because of the fascination of these wireless problems for physicists that the International Scientific Radio Union has become such a great success. The subject especially lends itself to interaction between physicists and engineers. There are many examples. As one example I might mention that when Lenard about 1900 introduced a grid into a photoelectric tube so as to accelerate the electrons, and then investigated their motion and nature after they had come through the holes in the grid, he thereby invented the principle of the triode; and when von Baeyer in 1907 conveyed this principle (quite intentionally) from the photoelectric tube to the thermionic tube he unknowingly constructed an amplifier tube. If you make up, as I have done, some of von Baeyer's tubes according to the specification in his paper they are very good amplifiers. A few months earlier than von Baeyer, de Forest introduced a grid into a soft vacuum tube for the purpose of improving its detecting efficacy, but strangely enough his tube was less practical than von Baeyer's tube, which did not enter engineering practice until some years later. That is an instance where physicists have unintentionally introduced principles and apparatus into wireless engineering. As another example one might take an experiment of J. J. Thomson, who deflected a stream of electrons into a small metal box in order to count them. When he did that he was anticipating von Lieben's amplifier, which worked on precisely that principle.

One can take other examples directed in the opposite direction. For instance, when it was found necessary towards the end of the War to stabilise electric oscillations by means of mechanical objects in vibration, the physicists solved the problem on demand. In that case the action by the physicists was intentional. But the mutual relationships could be multiplied indefinitely, and the result on the whole is that there has been a vast network of such relationships established; which explains why to this day the combination of engineers and physicists like this Union has been so stable.

Another fear I might mention that weighed upon the founders of these Unions when they came to consider the possibility of a Radio Union, was that membership might be limited, and the presentation of valuable communications made difficult, by the fact that many prospective members were engaged in the employ of large industrial firms. This fear has also proved baseless. Many of our most valued members are employees of engineering firms. It speaks very well for the public spirit of the great industrial corporations that they permit their men to communicate to this Union many valuable and original papers.

This Union has recently taken a very important part in the second Polar Year. At the date of the first Polar Year 50 years ago Hertz had not created, detected and measured electromagnetic waves, so radio played no part in that Polar Year, although atmospherics were doubtless running about the globe and although the ionosphere was present and awaiting investigation. In the second Polar Year the study was organized by a special sub-commission of this Union and the results will form the subject of communications at the technical meetings during the coming week. The results of this work are so important that it seems desirable to keep the sub-commission in being and to make Polar Year work a continuous operation as far as possible.

Another great piece of work recently carried through by the Union was that upon the solar eclipse of 1932. Preparations must begin almost at once for the 1937 eclipse. Beside the two great efforts mentioned there has been much work on atmospherics, on laboratory methods, on the propagation of waves over great and small distances, on the generation of very short waves, and on certain mathematical matters relating to wireless problems. These are sufficient to demonstrate to the world that our Union has thoroughly justified its existence.

We have all met here to carry through a heavy programme of technical work and social engagements. Dr. Rayner is in charge of these last matters especially, and he has taken a full load of the work. So I will ask him to tell us something of our programme of excursions and something of our duty towards the office in keeping the office and him in touch with us.

Après ces paroles, *M. le Dr. E. H. Rayner*, Président de la Commission I et du Comité de Réception, expose à l'assistance l'organisation et les horaires prévus pour les travaux de la V^{e} Assemblée Générale, ainsi que ceux des excursions et visites projetées.

Des applaudissements accueillent son exposé.

Les débats se poursuivent par une séance administrative.

Séance Administrative du mardi 11 septembre

Business Meeting held on Tuesday, September 11

La séance est ouverte à 4 heures, sous la présidence du Dr. ECCLES, Vice-Président de l'U. R. S. I.

Dr. Eccles. — The first item of business for the meeting is to send a message to Professor Kennelly from the gathering. Professor Appleton has kindly written out a motion to which I think all will agree.

« *To Prof. Kennelly.* The members of the U. R. S. I. gathered in London send an expression of affectionate regard to their absent President, and greatly deplore both his absence and the reason for it. They wish him a speedy and complete return to his usual health and activity. » (*Agreed*).

The next item of business is to ask Professor Appleton, to give us a communication of our future work.

Prof. Appleton. — Mr. President, Gentlemen, Dr. Rayner's concern has been to see that you have plenty of entertainment and it is now my concern to see that, no only are you entertained but that you do some work, and so I want to say a few words about the organization of the programme. First I want you to have in your hands the little book which has the programme of work.

You will see that on Friday September 14th in the morning we are to discuss the results of the Polar Year. It is quite clear that that discussion is going to be a long and important one and there will be quite a number of communications from many countries, and it seems to me that the afternoon also should be used for the same discussion. In the afternoon we have Commission III, and Commission III has a lot of work to do, so I propose that we make Commission III the Tuesday morning September 18th at 9.45 a. m. Commission IV will be put back to Friday because it has, so far as we know, no work to do this session.

The next announcement deals with the work to-morrow morning, Wednesday September 12th, short meetings of Commission I, II, III and V. I hope the President of each Commission will decide beforehand how the 3/4 hour to be given to each Commission will be used.

Organization of work; Number of Sub-Commissions; Personnel of Sub-Commission and time of first meeting of Sub-Commissions. It will be necessary to have extra meetings of certain Commissions, e. g. Commission II. I think it is essential that extra meetings of the commissions should not overlap, but Sub-Commissions will have to overlap very considerably. For such meetings we have 3 rooms, A, B and C, for Sub-Commissions. Meetings of the Commissions will be held in this room. Rooms open for working in until 8 p. m.

There is the business side of the Union's activities. There will be meetings of the Executive and Finance Committees. I should like members of the Executive Committee and Finance Committee to hand in their names to M. Dorsimont before leaving the building. The first meeting of the Executive Committee will take place to-morrow evening at 5.30 p. m. (Wednesday September 12th).

Le *Dr. Goldschmidt,* Secrétaire Général, donne lecture de son rapport sur l'activité de l'U. R. S. I. (1)

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(1) Voir page 10.

Prof. Appleton. — I am sure we are extremely indebted to the General Secretary for this very extensive and intimate survey of our activities, but of course the sad part of it to me is the state of our finances, and I think that one of the most important duties of the Executive Committee will be to see that sufficient money is coming in. I would like to remind the members of the Executive Committee of the very important meeting to-morrow evening at 17.30.

Dr. Eccles. — It is impossible to discuss the proposed alterations to the Statutes or to discuss the financial budget and accounts until after the Executive Committee has met. Will the meeting consent to the Executive Committee considering this carefully and tendering to the General Assembly a reasoned report ? (*Agreed*).

That concludes the business of this meeting.

Dr. Van der Pol. — I have had a letter from Professors Mandelstam and Papalexi that they are unable to be present but they send an extensive report on their work for discussion in Commission V. From Professor Kryloff, I received a letter stating that he was trying to come to London now but he has also sent me a report which I have here and which can be distributed amongst the members. So far neither Professor Mandelstam, Papalexi nor Kryloff are present.

RAPPORT DU SECRÉTAIRE GÉNÉRAL

CHAPITRE I

ACTIVITÉ DU SECRÉTARIAT GÉNÉRAL

La IV^{e} Assemblée Générale de l'U. R. S. I., tenue à Copenhague en 1931, avait adopté au cours de sa séance de clôture, une série de résolutions, groupées par Comité ou Commission, et la V^{e} Commission y avait proposé et rédigé un règlement qui devait servir de base à la préparation des travaux de la présente Assemblée (¹).

Le Secrétariat Général a pris à cœur de se conformer, autant qu'il le pouvait, à l'expression du désir unanime des Membres de l'U. R. S. I., et vous présentera le rapport succinct de son activité en suivant l'ordre des Annexes n° I à XII du Compte-rendu de la séance plénière de clôture de la IV^{e} Assemblée Générale (²).

1. — Annexe I. Résolutions proposées par le Comité Exécutif

L'Assemblée Générale avait décidé de maintenir dans leurs fonctions les Membres du Bureau et les Présidents des Commissions.

Une douloureuse fatalité s'est opposée à la réalisation de ce vœu. Le 16 février 1932, notre vénéré Président, le Général Ferrié était enlevé par un cruel destin à notre sincère admiration et à notre profonde affection.

Le Général Ferrié était non seulement le premier Président de notre association mais, en réalité, il en était le fondateur. C'est lui qui fit acquérir à l'Union son caractère hautement utilitaire et universel indiscuté, et il sut grouper sous son égide les savants les plus éminents du monde entier spécialisés dans la science qui nous est chère.

Redire ici son rôle primordial, montrer son influence animatrice, rendre tangible d'une façon complète la haute valeur de sa si compétente direction et des conseils éclairés qu'il ne cessait de prodiguer est une tâche qu'un rapport tel que celui que j'ai l'honneur de vous faire ne pourrait, hélas, pas entreprendre.

Je compte sur vos sentiments de profonde reconnaissance, Messieurs, pour apprécier toute l'étendue de la précieuse et inoubliable collaboration du regretté Général Ferrié et comprendre que les débats qui s'ouvrent

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(¹) U. R. S. I., vol. III, p. 97 et 110.
(²) Idem, p. 108.

aujourd'hui, vont encore se poursuivre imprégnés de sa haute pensée, à laquelle ils doivent leur ampleur remarquable, leur intérêt profond et leur haute valeur scientifique.

C'est devant cette perte immense que l'U. R. S. I. et son Secrétariat Général se sont trouvés peu après la IV^e Assemblée Générale.

Il fallait au cher disparu un successeur capable de reprendre son rôle primordial et de poursuivre son œuvre.

Les Etats-Unis d'Amérique, en la haute personnalité de M. le Dr. L. W. Austin, ont répondu à notre appel. Vice-Président de l'U. R. S. I., doté de l'autorité scientifique que son nom évoquait immédiatement dans le monde entier, le Dr. Austin accepta d'être pour nous un guide compétent, plein de clairvoyance et de sollicitude.

Hélas, à peine avait-il pris la haute direction de notre Union qu'il tombait lui aussi, frappé par le sort le 27 juin 1932.

Nous le regrettons amèrement non seulement pour lui-même, le plus précieux des amis de l'U. R. S. I., mais aussi pour la science profonde qu'il nous eût apportée et la précision de son esprit clairvoyant qui aurait ordonné nos travaux.

C'est alors que nous tournant à nouveau vers les Etats-Unis, nous avons sollicité M. le Prof. A. E. Kennelly de bien vouloir se charger de la lourde responsabilité de la double succession. Il hésita longtemps, mais devant notre insistance il acquiesça.

Selon l'usage, le Secrétariat Général lui offrit sa démission, mais il nous pria de poursuivre la tâche à l'accomplissement de laquelle nous continuons à mettre tout notre dévouement.

Sa présence était pour l'U. R. S. I. un gage sûr de continuation des traditions de travail, qui avaient jusque-là été celles de notre Union.

Peu après le décès de son premier Président, l'U. R. S. I. vit encore, avec douleur, disparaître M. le Dr. Dye, Président de la première Commission de notre Union. Le souvenir du cher disparu est encore très vivant parmi nous car la dernière Assemblée Générale nous l'avait montré si affable et si dévoué à notre activité. Le Comité National Anglais et avec lui l'Union entière, ont perdu un savant érudit, un Membre des plus actifs et un Président écouté.

M. le Dr. E. H. Rayner, à notre demande, a bien voulu se charger de la fonction qu'avait assumée le Dr. Dye.

La fatalité s'est ainsi acharnée contre les vœux émis par notre dernière Assemblée Générale et le Secrétariat Général a connu une longue période où son activité s'est concentrée principalement à assurer, malgré les rudes coups du destin et au prix d'efforts persévérants, la continuité indispensable à l'aboutissement des travaux, constituant en quelque sorte l'hommage ultime de l'Union à la mémoire des chers disparus.

Des propositions nouvelles du Comité Exécutif sont désirables pour garantir cette continuité et je me permettrai de les signaler à la fin de ce rapport.

Le Secrétariat Général pour répondre au 2° des Résolutions du Comité Exécutif a entrepris des démarches afin d'obtenir l'adhésion de nouveaux pays à l'U. R. S. I.

L'Union des Républiques Soviétistes Socialistes et l'Allemagne ont été pressenties.

Les pourparlers n'ont pas encore abouti avec l'U. R. S. S. Toutefois, grâce à l'aimable intervention de M. le Dr. van der Pol, qui a bien voulu nous aider de son influence, MM. les Prof. Kryloff, Mandelstam et Papalexi, éminents délégués de l'U. R. S. S., ont bien voulu participer aux travaux de notre Assemblée Générale et s'ils ne sont pas parmi nous, les études qu'ils nous ont envoyées témoignent de l'intérêt que ces savants portent à notre Union.

Pour ce qui concerne l'Allemagne, nous avons fait part à M. le Prof. Wagner de ce que la modification des statuts du Conseil International des Unions Scientifiques, permettait l'adhésion de l'Allemagne à l'U. R. S. I.

Il semble se dégager d'une récente correspondance que M. le Prof. Wagner est sur le point de réussir dans les démarches qu'il fait activement auprès de son gouvernement et peut-être a-t-il, à l'heure présente, une heureuse nouvelle à nous annoncer. Nous le souhaitons vivement pour le grand profit que procurerait la présence d'éminentes personnalités scientifiques dont la collaboration nous serait ainsi acquise.

Grâce à l'heureuse intervention du Comité National Français, auquel nous exprimons notre gratitude, un Comité National Marocain a été constitué.

Nous espérons aussi pouvoir à bref délai compter parmi nous des représentants de la nation Polonaise. M. le Dr. Lugeon a bien voulu nous promettre son aide pour amener cette précieuse adhésion.

2. — Annexe II. Résolutions proposées par le Comité Financier

Le Secrétariat Général avait pour mission d'assurer l'existence financière de l'U. R. S. I. jusqu'à la présente Assemblée.

Je ne pourrais dire que « c'est chose faite ». Les temps si durs pour toutes les nations de l'Univers que nous subissons en ce moment, ont une sévère répercussion sur notre situation financière.

Deux Comités Nationaux, l'Australie et l'Union Sud-Africaine, ont dû cesser toute coopération officielle par suite du manque de crédits. Nous continuons cependant à leur faire part des décisions essentielles de notre Union et nous leur avons fait savoir que nous considérions leur abstention comme purement temporaire et provisoire et que leur retour, dès les temps meilleurs, était attendu et souhaité ardemment par tous nos adhérents.

Comme vous le montreront les bilans des exercices 1931-1932, 1932-1933, 1933-1934 — annexés au présent rapport (¹), plusieurs Comités Nationaux n'ont pas effectué le payement de leurs versements statutaires.

D'autre part, malgré nos efforts, la vente du Volume III, issu de l'Assemblée Générale de Copenhague, n'a pas été rémunératrice, — 139 volumes seulement ont été vendus.

Il serait souhaitable de voir les Comités Nationaux s'engager à assurer effectivement l'achat partiel de l'édition, ainsi que cela fut déjà demandé lors de la IV^e Assemblée Générale.

Malgré cet état de choses, grâce aux plus strictes économies, grâce au désintéressement des collaborateurs techniques du Secrétariat Général, — auquel je rends ici un hommage public — réduisant spontanément leur rétribution, grâce aussi à ce que leur nombre a pu être ramené de trois à deux, cette année nous avons pu remplir la mission qui nous fut confiée. Mais c'est avec une réelle insistance que nous vous soumettons l'urgence d'une augmentation de la contribution statutaire ou toute autre mesure en raison des prévisions peu rassurantes que nous ne pouvons négliger d'envisager.

3. — Annexe IV.
Résolutions de la Commission I

L'activité des Commissions au cours des années 1932-1933 et 1934 s'est manifestée par des travaux résumés par les nombreux documents qui nous ont été adressés en vue des débats de la présente Assemblée Générale et que vous avez en mains (¹).

Les sujets suivants ont été proposés pour les travaux de la *Commission I* :
par son Président :

1) Utilisation d'émissions radio-électriques à grande stabilité de fréquence de l'onde porteuse ou de modulation, (*a*) en vue de comparaisons internationales et (*b*) en vue de l'étude de phénomènes physiques.

2) Utilisation simultanée de deux ou de plusieurs fréquences porteuses modulées par la même source, en vue des buts proposés en 1.

3) Valeurs des fréquences porteuses et des fréquences de modulation à utiliser pour réaliser les 1 et 2.

(¹) Voir. p. 18.

(¹) Voir listes de ces documents p. 23, 31, 60, 82.

4) Utilisation de quartz et d'autres oscillateurs dans des buts astronomiques et géodésiques.

5) Utilisation d'émissions radio-électriques dans des buts astronomiques et géodésiques.

6) Stabilisation des fréquences de l'ordre de 1000 mégacycles par seconde (0,3 mètre de longueur d'onde).

7) Mesure de l'intensité du champ électrique aux radio-fréquences.

par le Comité National Américain :

1) Définition de la hauteur effective d'une antenne.

2) Mesure de l'efficacité du rayonnement d'une antenne le long du sol et suivant un angle avec celui-ci.

3) Mesures radio-électriques aux fréquences ultra-hautes.

4) Méthodes de mesures des logarithmes et des autres constantes des plaques de quartz.

5) Ponts de radio-fréquences.

4. — Annexe V.

Résolutions de la Commission II et Sous-Commission de l'Année Polaire. Annexe III

Sujets proposés pour les travaux de la *Commission II* :

par son Président :

1) Mesure des hauteurs de la couche de l'ionosphère.

2) Relations entre les hauteurs des couches et les autres données cosmiques et géophysiques.

3) Données sur la propagation résultant du trafic commercial (Comité National Français).

4) Année Polaire (Sous-Commission).

5) Echos à longs retards.

6) Intensités des ondes reçues en fonction de la fréquence, du temps, etc...

7) Relations entre les intensités des ondes reçues et d'autres données cosmiques et géophysiques.

8) Variations dans la direction et la polarisation des ondes.

9) Eclipses.

par le Comité National Américain, en plus des sujets proposés ci-dessus :

Effets directifs dans le plan vertical et variations avec les troubles magnétiques.

5. — Annexe VI

Résolutions de la Commission III

Sujets proposés pour les travaux de la *Commission III* :

par son Président :

1) Enregistrement des atmosphériques :

a) Méthodes ;

b) Choix des fréquences centrales ;

c) Echange d'enregistrements entre les organismes intéressés.

2) Atmosphériques venant d'une direction fixe dans l'espace interstellaire.

3) L'étude des phénomènes de l'éclair.

Cette discussion portera sur les deux études suivantes :

a) « La nature des atmosphériques telle qu'elle est vue par l'oscillographie à rayons cathodiques » par le Prof. E. V. Appleton et M. R. A. Watson-Watt.

b) « Quelques résultats d'enregistrements oscillographiques à rayons cathodiques effectués en Suède » par le Prof. H. Norinder.

4) « Localisation de sources par goniomètres à rayons cathodiques ». Cette discussion sera ouverte par M. R. A. Watson-Watt.

par le Comité National Français :

1) Enregistrement quotidien :

a) Réseau de stations ;

b) Méthodes ;

c) Ondes internationales d'enregistrement ;

d) Echange des résultats.

2) Goniométrie :

a) Goniométrie instantanée ;

b) Goniométrie moyenne.

3) Rapports entre les atmosphériques et la propagation des ondes :

a) Influence de la propagation sur l'évolution des atmosphériques ;

b) Influence des sources (éclairs et autres décharges) sur l'ionosphère et la propagation.

par le Comité National Américain :

1) Enregistrement des atmosphériques :

a) Méthodes;

b) Emploi de 12, 50 et 90 kc/s pour l'observation;

c) Echange d'enregistrements entre les organismes intéressés.

2) Localisation de sources par goniomètres à rayons cathodiques.

3) Etude des phénomènes de l'éclair.

4) Atmosphériques venant d'une direction fixe dans l'espace interstellaire.

6. — Annexe VII
Résolutions de la Commission IV

Sujets proposés pour les travaux de la *Commission IV* :

par le Comité National Américain :

1) Codes pour Ursigrammes.

2) Extension du service des Ursigrammes (données sur les atmosphériques et l'ionosphère fournies par la Grande-Bretagne).

3) Etude de la réception à haute fréquence par les amateurs, etc...

4) Mesures de longitude par la radio.

7. — Sujets proposés pour les travaux de la Commission V

par son Président :

1) Discussion du rapport de MM. Appleton et Gutton sur « L'étude en laboratoire des gaz ionisés ».

2) Discussion du rapport de MM. Chapman et le R. P. Lejay sur « La nature de la radiation solaire et la composition de la haute atmosphère ».

3) Discussion du rapport de M. le Dr. K. W. Wagner sur « La génération des ondes de moins de 1 mètre de longueur d'onde ».

4) Discussion du rapport de M. van der Pol sur « Les principes du calcul opérationnel (symbolique) et son application à la radioélectricité ».

5) La théorie non linéaire des oscillations électriques.

par le Comité National Américain :

1) Données de laboratoire sur les gaz ionisés.

2) La nature de la radiation solaire et la composition de la haute atmosphère.

3) Génération d'ondes inférieures à 20 centimètres.

4) Calcul opérationnel en radio.

Une remarque toutefois doit être faite au sujet des documents reçus par le Secrétariat Général en vue de cette Assemblée.

Dans le but de faciliter les travaux auxquels vous allez avoir à vous livrer, les documents envoyés par les Comités Nationaux, les Présidents de Commissions, les Membres de l'U. R. S. I., devaient être traduits, reproduits et distribués avant l'Assemblée Générale.

En prenant cette décision, notre estimation approximative du nombre des travaux nous permettait de ne pas craindre les conséquences pécuniaires de cette disposition.

Il arriva toutefois que la quantité de mémoires, leur étendue, la multiplicité des planches et graphiques qu'ils comportent et dont la reproduction est coûteuse, dépassa largement nos prévisions. Si d'une part nous nous en sommes sincèrement réjouis, les présents débats devant s'ouvrir préparés par une activité remarquable des Commissions, nous avons dû, d'autre part, en dernière heure, modifier nos projets pour d'impérieuses raisons budgétaires.

Nous avons été amenés ainsi à solliciter des expéditeurs l'envoi de leurs documents en multiples exemplaires et surtout des graphiques en nombre suffisant d'exemplaires. En effet, il n'eût pas été possible pratiquement, faute de temps et de ressources, de reproduire tous les graphiques, planches, photographies, etc... joints aux documents.

Nous nous sommes bornés, quand il n'a pu être fait mieux, à les reproduire en quelques exemplaires seulement par des procédés de photographie industrielle. De cette façon, il y en aura suffisamment ici pour assurer la compréhension et la clarté des discussions.

Veuillez excuser ce contre-temps, amené par des raisons majeures d'économie forcée.

8. — Relations avec d'autres organismes scientifiques

a) Conférence Radiotélégraphique Internationale de Madrid, Septembre 1932. — Lors de la réunion à Madrid, en Septembre 1932, de la Conférence Radiotélégraphique Internationale, le Ministère des Communications de la République Espagnole avait invité l'U. R. S. I. à y envoyer des délégués pour assister aux débats.

Il fut décidé, après consultation des Comités Nationaux, que les Membres de l'U.R.S.I. assistant à la Conférence, y représenteraient notre Union et y agiraient éventuellement en son nom.

Aucun document n'a résulté de cette coopération.

b) Commission Electrotechnique Internationale, C. E. I. — La Commission Electrotechnique Internationale avait été sollicitée, à l'initiative du Comité Electrotechnique néerlandais, de réunir les organismes internationaux intéressés à l'étude des « Perturbations dans les Radio-Réceptions ».

L'U. R. S. I. fut invitée à prendre part à ces discussions. A la suggestion de notre regretté Président, M. le Général Ferrié, et après consultation générale des Comités Nationaux, notre Union ne prit pas part à ces travaux pour des raisons statutaires.

c) Conseil International des Unions Scientifiques. — Le Secrétariat Général s'est tenu en relation permanente avec le Conseil International des Unions Scientifiques à qui il a fourni, autant qu'il le pouvait, des renseignements sur ses travaux, la composition des différents Comités et Commissions de notre Union, nomination de représentants de l'U. R. S. I. auprès de différents organismes internationaux (Commission des Relations entre les Phénomènes Solaires et Terrestres — Comité des Instruments et Méthodes) créés par le Conseil.

Le Conseil International des Unions Scientifiques, a tenu à Bruxelles, en juillet dernier, une Assemblée Générale et la réunion de son Comité Exécutif.

A cette occasion, une notice de propagande, relatant l'activité des Commissions de l'U. R. S. I. a été distribuée par nos soins au siège même de ces réunions à Bruxelles.

L'U. R. S. I. a été heureuse de se présenter ainsi en témoignant de son ardeur à la tâche et de la haute signification scientifique et internationale de ses réalisations.

d) Union Géodésique et Géophysique Internationale (U. G. G. I.) Association de Magnétisme et Electricité Terrestres. — Le Président de l'U. R. S. I. a reçu de l'Association de Magnétisme et Electricité Terrestres de l'U. G. G. I. une adresse de remerciements pour la contribution de notre Union à l'étude des mesures de la hauteur et de l'intensité de l'ionisation dans la haute atmosphère.

Le Secrétariat Général a été heureux d'en faire part à tous les Comités Nationaux.

9. — Réunions tenues par l'U. R. S. I. au cours des années 1932 à 1934

Profitant du passage en Europe de son Président, M. le Prof. Kennelly, le Comité Exécutif de notre Union a été invité à se réunir à Paris et y a tenu le 10 octobre 1933 une réunion partielle.

Des délibérations fructueuses eurent lieu. Elles amenèrent la rédaction d'un compte rendu qui fut distribué aux Comités Nationaux et l'énoncé de propositions que je me permettrai de signaler plus loin.

10. — Coopération à l'organisation du Service des Ursigrammes

Le Secrétariat Général s'est attaché à favoriser autant qu'il l'a pu l'organisation de ce service d'écoute.

Il a assuré la retransmission des copies entre les différents services de réception et d'émission.

Il a transmis à tous les Comités Nationaux les codes publiés par les Comités Nationaux Américains, Français et Japonais concernant les renseignements relatifs à la couche ionisée de la haute atmosphère.

Il a également fait part de l'activité que le Comité National Japonais prenait à ce service.

Il s'est conformé en cela au désir de son Président, M. le Prof. Kennelly, et aux résolutions exprimées dans le compte rendu de la Réunion du Comité Exécutif à Paris en 1933.

11. — Documents U. R. S. I.

Le Secrétariat Général a publié et distribué aux Comités Nationaux pendant la période Juin 1931 à Août 1934, 94 documents numérotés n° 293 à 387, émanant des divers Comités de notre Union et dont la liste est annexée au présent rapport. (¹)

12. — Bibliographie

Le Secrétariat Général quoique ayant été forcé, pour des raisons budgétaires, à réduire, provisoirement tout au moins, de 3 à 2 ses collaborateurs techniques, a continué pourtant la publication intégrale et la distribution des références bibliographiques qu'il recevait des Comités Nationaux Américains, Français et Japonais.

Si le Service des Références Bibliographiques est actuellement moins complet, c'est par la suite de la défaillance du Comité National Américain, obligé, par suite de restrictions bugdétaires, de cesser le service des références.

Le Secrétariat Général a distribué aux Comités Nationaux depuis la dernière Assemblée Générale 35 fascicules de références bibliographiques.

CHAPITRE II

LES PROPOSITIONS DU SECRÉTARIAT GÉNÉRAL

Le Secrétariat Général insiste tout particulièrement pour que les propositions suivantes soient prises en considération :

1. — Par le Comité Exécutif

a) Nécessité de proposer à l'Assemblée Générale d'entériner les statuts établis à Bruxelles en 1928 et les modifications proposées par le Comité Exécutif lors de sa réunion de Paris et dont voici l'énoncé :

L'article 2 du Chapitre 1 : « L'admission d'un pays à l'Union est subordonnée aux conditions fixées par les statuts du Conseil International des Recherches » est supprimé.

Le 5ᵉ paragraphe de l'article 18 du Chapitre 7 : « Les protectorats diplomatiques et pays sous mandat jouissent du même droit » serait modifié comme suit : « Les protectorats diplomatiques, pays sous mandat et les colonies ayant un budget indépendant, jouissent du même droit. Leur cotisation sera fixée par le Comité Exécutif en tenant compte de leur activité scientifique. »

Il voudrait également voir tenir compte éventuellement des desiderata formulés par le Comité National Anglais ainsi que suit :

1. — « The meetings of the General Assembly shall be held not more frequently than once every two years ».

2. — « The President shall hold office from one General Assembly to the next and shall not be immediately re-eligible.

b) Nécessité de proposer les nominations nécessaires à la Présidence et aux Vice-Présidences, aux Présidences des Commissions et des Comités Exécutif et Financier.

c) Le Secrétariat Général désirerait également voir désigner par Comité et par Commission, un rapporteur chargé de l'aider dans son travail.

2. — Par les Comités Nationaux

a) Le Secrétariat Général désirerait obtenir des Comités Nationaux, et ce dans le plus bref délai, leur composition complète ainsi que les nominations auxquelles il a été procédé dans les cinq Commissions de l'U. R. S. I., afin d'assurer plus efficacement la diffusion des renseignements à transmettre.

b) Le Secrétariat Général propose aux Comités Nationaux, dans l'hypothèse où l'édition des travaux de la Vᵉ Assemblée Générale sera décidée, de bien vouloir assurer l'achat d'un certain nombre de volumes (10 par unité statutaire) afin de couvrir sûrement les frais d'édition.

(¹) Voir p. 20.

3. — Par la Commission Financière

a) Insister auprès des Comités Nationaux qui ne se sont pas encore libérés de leurs charges statutaires, de bien vouloir s'y appliquer de tous leurs efforts.

b) Modification de la cotisation statutaire qui devrait au moins être doublée.

c) Le Secrétariat Général insiste pour que les divers versements qui lui sont faits, soient libellés en « Belgas » de façon à éviter des pertes dues aux fluctuations des changes.

d) En conclusion, le Secrétariat Général se permet d'insister bien vivement auprès de la Commission Financière sur l'urgence extrême qu'il y a d'assurer, pour l'avenir, la situation financière de l'U. R. S. I.

Déjà chancelante lors de l'Assemblée Générale de 1928, la situation financière de notre Union s'était améliorée grâce aux généreuses libéralités que différents Comités Nationaux nous avaient consenties. Ils ont ainsi fourni à notre Trésorerie un apport supplémentaire de 132.119,10 francs, qui nous a permis d'équilibrer notre budget jusqu'à présent.

L'Assemblée Générale de Copenhague en 1931 avait déjà examiné le moyen de pouvoir équilibrer les recettes et les dépenses, la possibilité de nouvelles libéralités devant être considérée à ce moment comme exclue. Le Comité National Britannique avait proposé d'augmenter la cotisation statutaire et de porter celle-ci au double de sa valeur actuelle. Cette proposition avait été approuvée par les Comités Nationaux des Etats-Unis d'Amérique, de Nouvelle Zélande, de Suisse et de Belgique.

Aucune mesure n'a pu, jusqu'à présent, recevoir un commencement d'exécution. Il est donc réellement indispensable d'adopter une solution ferme et efficace pour permettre l'édition des comptes rendus de la présente Assemblée et assurer la continuation de l'activité de notre Union. Son existence dépendra des mesures qui seront prises.

4. — Par les Commissions

a) Le Secrétariat Général propose l'adoption par toutes les Commissions et leur observation plus stricte, des résolutions exprimées à Copenhague par la Commission V (Annexe 1 — Page 96 du Recueil des Travaux de l'Assemblée de 1931).

De cette façon la préparation de la future Assemblée Générale pourrait se réaliser d'une façon plus efficace encore.

Il insiste particulièrement pour que les délais de fourniture des divers documents devant servir aux débats des Assemblées Générales soient respectés.

b) Il demande qu'à l'avenir les documents devant servir aux débats des Assemblées Générales lui soient fournis en 100 exemplaires. Le Secrétariat se chargerait de la traduction et de la reproduction de ceux-ci au nombre d'exemplaires nécessaires. Toutefois les planches et graphiques devraient lui être fournis par les soins de l'auteur.

CHAPITRE III

CONCLUSIONS

Le Secrétariat Général conçoit comme un réel devoir de remercier ses divers correspondants pour l'empressement et l'amabilité qu'ils lui ont toujours témoignés.

Il adresse à M. le Prof. Kennelly, le dévoué Président de l'Union, l'expression de sa gratitude pour les avis éclairés qu'il n'a cessé de lui prodiguer.

Il exprime au nom de l'Union sa reconnaissance aux Présidents des diverses Commissions de l'U. R. S. I. pour la façon remarquable et consciencieuse avec laquelle ils ont préparé les débats.

Il remercie enfin également au nom de l'U. R. S. I., dont il croit être l'unanime interprète, et ce de la façon la plus vive, le Comité National Britannique pour l'accueil grandiose et généreux qu'il fait cette année à nos réunions, ne négligeant rien pour que le cadre où se passeront les débats soit digne des nobles aspirations scientifiques de tous, et digne aussi de la traditionnelle et touchante hospitalité anglaise. Grâce à elle notre réunion prend pour la première fois peut-être les proportions d'un réel congrès international.

Ayant exposé son rôle modeste, le Secrétariat Général, en réitérant ses remerciements pour les facilités lui apportées par la collaboration de tous, renouvelle comme par le passé les assurances de son entier et attentif dévouement au service de l'Union Radio-Scientifique Internationale qui lui est si chère.

Pour terminer, je demande la permission de remercier les dévoués collaborateurs du Secrétariat Général pour le travail très considérable fourni à des conditions particulièrement modestes.

ANNEXE 1 AU RAPPORT DU SECRÉTAIRE GÉNÉRAL

Exercice 1930-1931
(du 1er septembre 1930 au 31 août 1931)
Situation au 31 août 1931

Report au 30-4-1931		65.172,24
Recettes du 1er *mai* au 31 *août* 1931		
Cotisations :		
Belgique 1931	1.400,00	
Suisse 1931	690,80	
Union Sud Africaine 1931	695,00	
		2.785,80
Ventes brochures Ass. Gén.		
1927	2.596,35	
1928	3.473,80	
		6.070,15
		74.028,19
Dépenses du 1er *mai au* 31 *août* 1931		
Personnel du Secrétariat Collaborateurs techniques	9.000,00	
Impression documents et bibliographies Fournitures de bureau	1.294,95	
Frais expédition lettres et documents Débours divers	1.321,75	
Frais d'organisation Ass. Génér. 1931 Voyage secrétaire adjoint Impression et expédition documents	11.775,10	
		23.391,80
Solde disponible au 31 août 1931		50.636,39

Exercice 1931-1932
(du 1er septembre 1931 au 31 août 1932)
Situation au 31 août 1932

Report au 1er septembre 1931		50.636,39
Recettes :		
Cotisations :		
Norvège 1930 et 1931	1.390,80	
France 1931	5.624,25	
Amérique 1931	5.529,60	
Italie 1931	5.580,95	
Japon 1931	5.536,45	
Danemark 1931	696,50	
Nouvelle Zélande 1931	685,00	
Hollande 1931 et 1932	2.800,00	
Suède 1931 et 1932	1.395,95	
Angleterre 1932	5.530,10	
Belgique 1932	1.400,00	
Suisse 1932	692,45	
		36.862,05
Ventes Brochures :		
Assemblée Générale 1927	12.935,20	
Assemblée Générale 1928	16.620,55	
Assemblée Générale 1931	5.350,60	
		34.906,35
		122.404,79

Total des recettes		122.404,79

Dépenses :

Personnel technique et bureau	43.000,00	
Impression documents	6.891,05	
Bibliographies		
Fournitures diverses		
Frais de correspondances	3.101,70	
Expédition documents		
Télégrammes		
Impression Vol. III Ass. Génér. 1931	12.810,67	
		65.803,42
Solde disponible au 31 août 1932		56.601,37

Exercice 1932-1933
(du 1^er^ septembre 1932 au 31 août 1933)
Situation au 31 août 1933

Report au 1er septembre 1932		56.601,37

Recettes :

Cotisations :

Danemark 1932	689,90	
France 1932	5.626,20	
Etats-Unis 1932	5.550,20	
Japon 1932	5.510,60	
Norvège 1932 et 1933	2.761,75	
Suisse 1933	688,70	
		20.827,35

Ventes Brochures :

Assemblée Générale 1927	569,75	
Assemblée Générale 1928	2.041,80	
Assemblée Générale 1931	5.941,65	
		8.553,20
		85.981,92

Dépenses :

Personnel technique et bureau	44.320,00	
Impression documents	5.284,90	
Bibliographies		
Fournitures diverses		
Frais de correspondances	2.030,70	
Expédition documents		
Télégrammes		
		51.635,60
Solde disponible au 31 août 1933		34.346,32

Exercice 1933-1934
(du 1^er^ septembre 1933 au 31 août 1934)
Situation au 31 août 1934

Report au 1er septembre 1933		34.346,32

Recettes :

Cotisations

Nouvelle Zélande 1932 et 1933	1.252,30	
Etats-Unis 1933	5.546,40	
Angleterre 1933	5.485,00	
Japon 1933	5.558,30	
Belgique 1933	1.400,00	
Hollande 1933	1.400,00	
Danemark 1933	695,00	
Maroc 1933	696,05	
France 1933 et 1934	11.243,20	
Suède 1933 et 1934	1.392,05	
Suisse 1934	691,20	
		35.359,50

Ventes Brochures :

Assemblée Générale 1927	95,00	
Assemblée Générale 1928	234,40	
Assemblée Générale 1931	181,55	
		510,95
		70.216,77

Dépenses :

Personnel technique et bureau	44.480,00	
Impression documents	4.347,50	
Bibliographies		
Fournitures diverses		
Frais de correspondances	1.211,17	
Expédition documents		
Télégrammes		
Frais de voyages	1.145,05	
Contribution Cons. Int. Recherches		
Dépenses pour travaux préparatoires à l'Assem. Générale de 1934	3.002,45	
		54.186,17
Solde disponible au 31 août 1934		16.030,60

ANNEXE 2 AU RAPPORT DU SECRÉTAIRE GÉNÉRAL
LISTE DES DOCUMENTS MIS EN CIRCULATION PAR LE SECRÉTARIAT GÉNÉRAL

Pendant la période écoulée entre la dernière Assemblée Générale de l'Union, tenue à Copenhague en Mai-Juin 1931 et celle de 1934, le Secrétariat Général de l'U.R.S.I. a mis en circulation, à l'usage de ses Membres, environ une centaine de documents dont ci-dessous la nomenclature (1) :

I. — Du Comité National Américain :

a) Ursigrammes. — Résultats des émissions d'Ursigrammes effectuées par les postes américains, français et japonais :

N° 287 : Cosmic data du 8 au 28 février 1931.
289 : » » 1er mars au 4 avril 1931.
292 : » » 5 au 25 avril 1931.
293 : » » 26 avril au 16 mai 1931.
295 : Modifications au code américain d'émissions Ursigrammes.
296 : Cosmic data du 17 mai au 6 juin 1931.
299 : » » 7 au 27 juin 1931.
301 : » » 28 juin au 18 juillet 1931.
304*bis* : » » 19 juillet au 8 août 1931.
305 : » » 9 au 29 août 1931.
308 : » » 30 août au 12 sept. 1931.
311 : » » 13 sept. au 3 oct. 1931.
312 : » » 4 au 24 octobre 1931.
315 : » » 25 oct. au 21 nov. 1931.
316 : » » 22 nov. au 17 déc. 1931.
319 : » » 20 déc. 1931-9 janv. 1932.
320 : » » 10 au 26 janvier 1932.
321 : » » 31 janvier au 20 fév. 1932.
323 : » » 21 fév. au 26 mars 1932.
326 : » » 27 mars au 16 avril 1932.
327 : » » 17 au 30 avril 1932.
329 : » » 1er au 21 mai 1932.
330 : » » 28 mai au 11 juin 1932.
331 : » » 12 juin au 4 juillet 1932.
334 : » » 10 au 23 juillet 1932.
335 : » » 24 juillet au 6 août 1932.
336 : » » 7 au 27 août 1932.
337 : » » 28 août au 3 sept. 1932.
341 : » » 4 au 17 septembre 1932.
342 : » » 18 sept. au 8 oct. 1932.
N° 343 : Cosmic data du 9 au 29 octobre 1932.
344 : » » 30 oct. au 19 nov. 1932.
346 : » » 20 nov. au 10 déc. 1932.
348 : » » 11 déc. au 7 janvier 1933.
350 : » » 8 janvier au 4 fév. 1933.
351 : » » 5 février au 4 mars 1933.
353 : » » 5 au 25 mars 1933.
354 : » » 26 mars au 15 avril 1933.
355 : » » 16 au 22 avril 1933.
358 : » » Ursigrams.
364 : » » du 23 avril au 3 juin 1933.
365 : National American Committee U. R. S. I. Meeting of the sub-committee on Unification of codes.
366 : Cosmic data du 4 juin au 8 juillet 1933.
368 : » » 9 juillet au 12 août 1933.
369 : » » 13 août au 2 sept. 1933.
370 : » » 3 au 23 septembre 1933.
371 : » » 24 sept. au 21 oct. 1933.
372 : » » 22 oct. au 11 nov. 1933.
373 : » » 12 nov. au 2 déc. 1933.
374 : » » 3 au 23 décembre 1933.
376 : » » 24 déc. au 13 janv. 1934.
377 : » » Ursigrams.
378 : » » 14 janvier au 10 fév. 1934.
379 : » » 11 février au 3 mars 1934.
380 : » » 4 au 24 mars 1934.
381 : » » 25 mars au 28 avril 1934.
382 : » » 29 avril au 19 mai 1934.
383 : » » 20 mai au 9 juin 1934.
384 : » » 10 au 30 juin 1934.
385 : » » 1er au 21 juillet 1934.
388 : » » 22 juillet au 18 août 1934.

b) Field intensity measurements of signals and atmospherics disturbances in Washington :

N° 290 : January and February 1931.
294 : March and April 1931.
300 : May and June 1931.
309 : July and August 1931.
314 : September and October 1931.
318 : November and December 1931.
325 : January and February 1932.
328 : March and April 1932.
332 : May and June 1932.
338 : July and August 1932.
345 : September and October 1932.
349 : November and December 1932.
352 : January and February 1933.
356 : March and April 1933.

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(1) Ces documents peuvent être obtenus au Secrétariat Général de l'U. R. S. I.

c) Radio transmissions of standard frequency :

N° 297 : July, August and September 1931.
306 : October, November and December 1931.
317 : New Schedule of radio transmission of standard frequency.
324 : Use of standard frequency transmissions in checking standard oscillators.
340 : Radio transmissions of standard frequency.
351*bis* : Change in schedule of radio transmissions of standard frequency.

d) Divers :

N° 357 : National American Committee U. R. S. I. Meeting of Committee on cooperation, April 27, 1933.

II. — Comité National Australien :

N° 359 : Radio Research Board, Report n° 1 :

I. — Corrections to field strenght measurements with Loop Antennae by W. G. Baker and L. G. H. Huxley.

II. — A radio field strength survey within 100 miles of Sydney by W. G. Baker and O. O. Pulley.

N° 360 : Radio Research Board, Report n° 2 :

I. — The state of polarization by sky waves by A. L. Green.

II. — Height measurements of the Heaviside layer in the early morning by A. L. Green.

N° 361 : Radio Research Board, Report n° 3 :

I. — The influence of the earth's magnetic field on the polarization of sky waves by W. G. Baker and A. L. Green.

N° 362 : Radio Research Board, Report n° 4 :

I. — A preliminary investigation of fading in New South Wales by A. L. Green and W. G. Baker.

II. — Studies of fading in Victoria : A preliminary study of fading on medium Wave-lengths at short distances by R. O. Cherry and D. F. Martin.

N° 363 : Radio Research Board, Report n° 5 :

I. — Atmospherics in Australia, I, by G. H. Munro and L. G. H. Huxley.

III. — Du Comité National Britannique :

N° 303 : Modifications proposées par le Comité National Britannique aux heures d'émissions d'Ursigrammes américains.
N° 339 : Emission of a frequency of 1.000 cycles per second, June 29-30, 1932.

IV. — Du Comité National Français :

N° 313 : Schéma d'émissions Ursigrammes faites par les postes radiotélégraphiques français.

V. — Du Comité National Japonais :

N° 291 : Twenty-four-hours receiving measurements of low frequency radio stations : Bolinas, Bordeaux, Kahuku, Malabar and Saïgon by E. Yokoyama and T. Tanimura.
N° 302 : Propagation of Wireless Waves by H. Nagaoka.
N° 307 : Twenty-four-hours receiving measurements of low frequency radio stations : Nauen and Warsaw by E. Yokoyama ans T. Tanimura.
N° 333 : Code des émissions d'Ursigrammes Japonais.
N° 333*bis* : Errata au document n° 333.

VI. — Du Comité National Néo-Zélandais :

N° 304 : Wireless Observations during the total solar eclipse of october 21-22, 1930 by M. A. F. Barnett.

VII. — Du Comité National Suisse :

N° 347 : L'éclipse de soleil du 31 août 1932 et le sondage par les parasites atmosphériques par le Dr. J. Lugeon.
N° 367 : Un fréquencemètre enregistreur à constante de temps par le Dr. J. Lugeon et J. Gurtzman.
N° 375 : L'ionosphère et la météorologie par le Dr. J. Lugeon.
N° 384 : Un relais à néon et son application à l'enregistrement des parasites atmosphériques par le Dr. J. Lugeon et J. Gurtzman.
N° 386 : Les parasites atmosphériques polaires par le Dr. J. Lugeon.

VIII. — De l'Union Internationale d'Astronomie :

Bulletin for Character figures of solar phenomena :

N° 286 : October-December 1930.
298 : January-March 1931.
310 : April-June 1931.
322 : October-December 1931.

IX. — Du Secrétariat Général :

N° 288 : Extrait du Journal Télégraphique de Berne : Notice au sujet de l'U. R. S. I.

Bibliographie

Pendant la même période, le Secrétariat Général a publié 35 fascicules de références bibliographiques émanant des Comités Nationaux Américain, Français et Japonais (¹).

(¹) Ces documents peuvent être obtenus au Secrétariat Général de l'U. R. S. I.

Travaux des Commissions

Proceedings of the Commissions

NOTICE HISTORIQUE

La Commission des *Méthodes de Mesures et d'Etalonnages*, la Commission de *Propagation des Ondes*, la Commission des *Perturbations Atmosphériques* et la Commission de *Liaison avec les Opérateurs, les Praticiens, les Amateurs et les Sciences Connexes* furent instituées par décision de l'Assemblée Générale de l'U. R. S. I. tenue à Bruxelles en juillet 1922.

La Commission de *Radiophysique* fut instituée sous le nom de Commission des *Oscillations* en octobre 1927, par l'Assemblée Générale de Washington ; cette dénomination fut changée lors de l'Assemblée Générale de Bruxelles, en septembre 1928.

L'activité des Commissions depuis l'Assemblée Générale de 1922 jusqu'à celle de 1931 est résumée dans les fascicules 3 à 6 du Volume I, dans le fascicule 3 du Volume II et dans le Volume III de l'U. R. S. I.

Au cours de l'Assemblée Générale tenue à Londres en septembre 1934, les Commissions ont résumé et discuté les études et travaux réalisés par les différents Comités Nationaux et elles ont élaboré des programmes de travaux pour l'avenir.

HISTORICAL NOTICES

The Commission on *Measurements and Standartization*, the Commission on *Radio Wave Propagation*, the Commission on *Atmospherics* and the Commission on *Cooperation with Operators, Practioners, Amateurs and Connected Sciences* were constituted by decision of the General Assembly of the U. R. S. I. held in Brussels in July 1922.

The Commission on *Radiophysics* was instituted under the name of Commission on *Oscillations*, in October 1927, by the General Assembly of Washington ; this denomination was changed during the General Assembly held in Brussels in September 1928.

The activity of the Commissions from the General Assembly of 1922 until the General Assembly of 1931 is summarized in fascicules 3 to 6 of Volume I, fascicule 3 of Volume II and in Volume III of the U. R. S. I.

During the General Assembly held in London in September 1934, the studies and works undertaken by the various National Committees since the General Assembly of 1931 were summarized and discussed, and programmes of works for the future were elaborated.

COMMISSION I. — MÉTHODES DE MESURES ET D'ÉTALONNAGES

COMMISSION I. — MEASUREMENTS AND STANDARTIZATION

INTRODUCTION

Les documents ci-après concernant la Commission I furent mis en circulation avant l'Assemblée Générale (¹) :

The following papers concerning Commission I were circulated before the General Assembly (¹) :

N° 4. — Report on the Work organized on behalf of the Commission since the Session in Copenhagen in 1931, by Dr. E. H. Rayner, President of the Commission.

N° 13. — Precision Measurements of Carrier Frequencies by the aid of a Valve-Driven Tuning Fork, by S. Gejer.

N° 14. — Measurement of Velocity of Radio Waves, by Dr. A. N. Goldschmith.

N° 17. — Radio Field Strength Measurement, by Carl R. Englund.

N° 23. — Effective Height of Antennae, by P. E. Watson.

N° 24. — A Determination of some of the Properties of the Piezo-Electric Quartz Resonator, by Karl S. Van Dyke.

N° 27. — Report of Radio Research in Japan, by the Japanese National Committee.

N° 33. — Thermal Characteristics of Piezo-Electric oscillating Quartz Plates, by I. Koga.

N° 34. — Quartz Plates with a very small Temperature Coefficient of Oscillation Frequency, by S. Matsumba and S. Kanzaki.

N° 39. — Note on the Generation of Stable Ultra-High Frequency Oscillations, by Fr. A. Kolster.

N° 42. — Radio-Frequency Standards, by E. L. Hall, V. E. Heaton and E. G. Lapham.

N° 43. — A High-Frequency Electrodynamic Ammeter, by H. M. Turner and P. C. Michel.

N° 48. — Intercomparison of Frequency Standards by means of a modulated Radio-Wave, by K. Takatsu, K. Tani and Y. Kusunose.

N° 49. — Observations effectuées le 14 mars 1934, par B. Decaux et J. B. Galle.

N° 50. — Report of the British National Committee to Commission I on Methods of Measuring Radio Field Intensity.

N° 51. — Measurement of Frequency, by L. Essen.

N° 52. — La Précision des Horloges à Quartz dans les Services Horaires, par N. Stoyko.

N° 61. — On the Adoption of a Criterion for Rating Broadcast Antennae according to the Proportion of the Total Radiated Energy which is confined to small angles to the horizontal, by W. A. Steel.

(¹) Voir les résumés, p. 120.

(¹) See abstracts, p. 120.

Séance d'ouverture du mercredi 12 septembre.

Opening Meeting held on Wednesday, September 12th.

La séance est ouverte à 14 h. 30 sous la Présidence du Dr. E. H. Rayner, Président de la Commission, assisté de M. Vigoureux comme Rapporteur.

The President. — The meeting will I know wish me to put on record their great regret at the death of the late Dr. Dye, who was formerly President of the Commission.

L'assemblée se recueille pour honorer la mémoire de feu le Dr. Dye.

The President then reads abstracts from his report to the Commission (¹), in the course of which he says : « I should like to aknowledge my own indebtedness and the indebtedness of the U. R. S. I. to my colleague, M. Essen of the National Physical Laboratory, who has carried out all the measurements referred to at Teddington, on which this report is based ».

At the conclusion of the reading of the report he says : « We have two main subjects under discussion, first there is frequency to which I have alluded, and secondly there is the subject of the measurement of radiation of the field strength.

We have a report which has been compiled as a result of the meeting at Copenhagen, when the URSI I think was asked by the C. C. I. R. to study the question of measurements of field strength, which is of great importance from the commercial point of view. Dr. Dye offered the services of Commission I for that purpose, and that has been done. An elaborate questionnaire was circulated to all countries concerned and other people interested in this work. The results of the questionnaire have been collected by Dr. Smith-Rose in what I consider is a really valuable document. You who have been members of the URSI for the last two or three meetings know what valuable reports he has made to the URSI on different subjects. I suggest that we form two sub-commissions for further work of this Commission, one on frequency and one on the measurement of field strength and other questions connected with radiation and antennae. I should also like to suggest that Dr. Smith-Rose be the Chairman of the second sub-commission. He is much more competent to deal with the subject than I am.

One particular subject which I think we ought really seriously to consider, which I have indicated here, is that the technique of radio transmission promises to be of the very greatest value to geophysics. There is in progress at the present time the survey of gravity over different parts of the world. Recently, work in England and in Africa, has been carried out, depending on radio methods for obtaining the time of the swings of the pendulum, requiring an accuracy of measurement of time intervals of a few hours or a few minutes to one part in a million. That is quite difficult to get in a foreign country, but we have in radio a great possibility of assisting that kind of work in geophysics.

I do not mention for the moment astronomy. I feel that in a few years the pendulum clock may disappear from the astronomical observations and the quartz radio oscillator will take its place, but we have the possibility here by sending out special types of time signals, or specially accurate continuous waves or special modulations, of assisting the geophysicists in all parts of the world. Work is being done at Cambridge in this line, but they have not been able to depend on the accuracy of international time signals, and they have used indirect methods, using Rugby transmission on commercial operation to obtain their time.

A few months ago a request came from the Central Office in Brussels that they had received from the Secretary of the International Research Council, a request for information from all the international councils under the International

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(¹) Document nº 4, p. 122.

Research Countil on the progress of their work which could be generally circulated. We of the U. R. S. I. know our own progress but others do not, and the Chairmen of the various sections were asked to transmit to Brussels, and so to the Secretary of the International Research Council, an account of their doings, and in my own particular report I mentioned the subject of the possible assistance of radio waves and radio methods for accurate time measurement, and I also on my own responsibility suggested that the time might come when the mean solar second should not be used for frequency measurements of the highest precision, that we should use the sidereal second because the sidereal second is the one thing which you establish in the astronomical laboratory.

We have a number of papers here (1). N° 13, 14, 24, 39, 42, 43, 51, are of the nature primarily of measurement of frequency. N° 43 suggests a satisfactory high frequency ammeter. N° 17, from the United States on field measurements, and N° 50, Report of Dr. Smith-Rose. My suggestion is that we refer those subjects to sub-commissions for further consideration.

Dr. Eccles. — Dr. Rayner has not suggested whether these sub-commissions should meet simultaneously or not. There are many members here present who would like to attend both sets of meetings if possible.

The President. — I think that they should not meet simultaneously.

As regards this Commission I have requested my collegue M. Vigoureux, (who many of you know by his work on this subject and his collaboration with Dr. Dye, and who has written a most important book on the piezo-electric properties of quartz and has carried out much research work on the subject at Teddington), to act as reporter for Commission I. He has the great advantage of speaking equally well French and English.

Dr. Eccles. — As no-one wishes to say anything in the way of comment upon your report or address, I should like to suggest that we thank the President for the care and trouble he has taken in preparing this address, and that we admire very much his suggestions for gravity and geophysics generally. I hope that some of those suggestions, especially the one in regard to sidereal time, will be considered carefully during the sitting of the Commission.

The President. — I propose then, if it is agreed, that this afternoon first of all be devoted primarily to the subject of frequency and so on, and that later in the afternoon I will ask Dr. Smith-Rose to take my place and to discuss the measurement of field strength. We will leave for the moment the amount of time to be devoted to each subject indefinite. If any members like to make any suggestions in the meantime for this afternoon, please tell me, Dr. Smith-Rose or M. Vigoureux.

Séance plénière du mercredi 12 septembre.
Full Meeting held on Wednesday, September 12th.

La séance est ouverte à 16 heures sous la présidence du Dr. E. H. Rayner.

The President. — We will now, with your permission, resolve ourselves into a sub-commission, and I suggest we discuss first the question of frequency and then the subject of field strength.

On the subject of frequency we have a number of papers which have been circulated, and I think we had better discuss a few points first, to get some idea of the importance of the work and a programme for future work. The work on frequency measurement as regards the URSI has been largely inter-comparison of national standards of frequency. The first thing we have to decide, I think, is whether it is desirable to continue this work of inter-comparison of standards of frequency in various countries. As you know, that can be carried out either by a radio frequency,or by a modulation frequency. Both have their advantages, and in this country we have largely used the modulation frequency. In America they use the carrier frequency. I believe that at present there is a high standard of steadiness commercially speaking at Rugby, but it does not attempt to have the steadiness which is now available for sources used for radio frequency standards; but it has a world-wide range and it promises to be a very valuable station for the transmission of time for geophysical and other purposes provided the frequency can be maintained with sufficient accuracy.

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(1) See page 23.

I have suggested another subject, which is the possible use of sidereal time for geophysical work. Geophysical work should have the highest accuracy available, and it does not matter whether you use a sidereal or a mean time second for such purposes, and it seems to me that there must be a diminution in accuracy in deriving solar time from sidereal time.

There is also another matter which I want to mention. There is one paper here on the measurement of current, nº 43 (¹). Prof. Turner who has given us this paper is unable to remain in England after to-morrow morning, and he would like it considered while he is here. In his paper he gives some results showing considerable discrepancies between different methods as the frequency increases. He considers that it wouls be useful to have a short discussion on the measurement of current at high frequency.

I do not think I need occupy your attention any more, but I should like first of all the opinion of the meeting as to the continuation of emission for the purpose firstly of intercomparison of national standards of frequency, and secondly for purposes of studying the physics of radio propagation. In my report I have given in some detail the results so far obtained, using the same modulation for two carrier frequencies simultaneously.

Prof. Jouaust. — Je pense que les mesures de fréquences transmises par radio doivent être continuées. Dans mon laboratoire nous sommes occupés à améliorer les appareils pour obtenir une précision plus élevée, et il est hautement désirable à ce point de vue que les comparaisons internationales soient continuées.

Prof. Yagi. — Our country is so far from Europe that we are unable to send anything special for that purpose. With regard to the method of comparison it seems to be better for us to use a modulation frequency, as we are still afraid of the fact that the carrier frequency migth not be steady enough. Of I may refer to the work of frequency comparison carried out by our National Committee, we are only using the modulation of frequency in the experiments of our country.

Séance de clôture du mercredi 19 septembre.

Final Meeting of Wednesday, September 19th.

La séance est ouverte à 12 heures, sous la présidence du Dr. E. H. Rayner, Président de la Commission, assisté de M. Vigoureux comme Rapporteur.

The President. — Commission I was divided into two sub-commissions, one dealing primarily with standards of frequency, the use of steady frequencies for physical work; the second sub-commission dealing with measurements of field strength.

The sub-commissions have produced their resolutions. The members probably all have copies of them and if the members wish I will take them in order without reading them in order to save time (¹).

(¹) See p. 150.

(¹) See p. 108.

Les cinq résolutions présentées dans leurs formes définitives par la *Sous-Commission I* (Etalons de Fréquence) présidée par le Dr. Rayner, sont acceptées. Il en est de même des cinq résolutions présentées par la *Sous-Commission* 2 (Méthodes de Mesures de l'Intensité du Champ) présidée par le Dr. Smith-Rose (¹).

The President. — I thank all members who have helped in these matters, and I feel quite sure that as regards field strength we are distinctly breaking new ground. We have had most valuable experience from workers in all countries, and I am quite sure that it will lead to new progress in measurement and to further progress in technical application.

Paper from America asked to be put on agenda. I have obtained copies of a critical report of measurements made at the N. P. L. on behalf of the Electrical Research Association.

Sous-Commission 1. — Étalons de fréquence

Sub-Commission 1. — Frequency Standards

Séance du mercredi 12 septembre. — Meeting held on Wednesday, September 12th.

La séance est ouverte à 14.30 heures, sous la présidence du Dr. E. H. RAYNER, Président de la Sous-Commission.

The President opens the meeting by indicating various subjects requiring discussion. They are :

1. — International comparisons of frequencies by measurements of :

(a) the modulation frequency, and

(b) the carrier frequency, of wireless waves.

2. — Use of standard frequency transmissions for geodetic work on gravity.

3. — Study of the physics of radio propagation by comparisons between two carrier waves of different frequency, modulated by the same source.

4. — Measurement of current at high radio frequencies.

5. — Substitution of stellar time for mean solar time as unit of time for geodetic work on gravity.

Ces sujets furent discutés dans l'ordre ci-dessus.

Prof. Yagi says that Japan is precluded from cooperating in frequency comparisons, by its distance from the other countries adhering to the Union.

The President has heard from Prof. E. Giebe that, as far as the Physikalisch-Technische Reichsanstalt is concerned, the comparisons are not of great use unless the frequency is steady to at least 1 part in 100 million.

Les résolutions 1 et 2 (¹) sont adoptées à l'unanimité pour être soumises à l'approbation de la Commission 1.

Colonel Angwin stating that the British General Post Office is willing to help by allowing standard frequencies to be transmitted from the long-wave station at Rugby, and

The President referring to the value of such transmissions in geodetic work on gravity, resolution 3 (²), in its final form is unanimously adopted for recommendation to Commission I.

Le *Prof. Jouaust* et le *Dr. Gorio* font remarquer la valeur de l'étude par l'oscillographe cathodique, de la transmission d'une modulation simple par deux ondes porteuses.

(¹) Voir p. 109.

(¹) Voir p. 108. (²) See p. 108.

La Sous-Commission décide à l'unanimité de recommander la résolution 4 (¹) à la Commission I.

Prof. Turner describes his work on the measurement of current at high radio frequencies.

Après une discussion à laquelle prirent part le *Prof. Jouaust*, le *Dr. Smith-Rose* et d'autres membres, la Sous-Commission, à l'unanimité, décide de présenter à la Commission I, la résolution 5 (¹) dans sa forme définitive.

Prof. Yagi refers to recent improvements in the technics of quartz oscillators, which could now be made to have an entirely negligible temperature coefficient of frequency.

Après introduction du sujet par le Président, le *Prof. Jouaust* fait remarquer l'avantage de l'emploi de la seconde sidérale par rapport à la seconde de temps moyen comme unité de temps pour les travaux scientifiques.

Il croit devoir donner également quelques renseignements sur la façon dont les observatoires déterminent la valeur de la seconde sidérale et la marche de leurs pendules. La conclusion est qu'à un instant donné la seconde sidérale, même évaluée avec la pendule d'un observatoire, n'est pas connue avec une très grande précision.

Dans les étalonnements faits au Laboratoire National de Radioélectricité, il faut attendre un temps assez long pour que le Bureau International de l'Heure puisse fournir la correction de la pendule utilisée, déduite de ses propres observations et de celles de divers observatoires qui enregistrent les signaux horaires.

Il est décidé à l'unanimité qu'il conviendrait d'attirer l'attention de tous ceux qui s'occupent de géodésie, sur les grands avantages qu'ils retireraient de l'utilisation, comme unité de temps, de la seconde sidérale au lieu de la seconde de temps moyen.

Sous-Commission 2. — Méthodes de mesure de l'intentisé du champ

Sub-Committee 2. — Methods of Measuring field Intensity

Séance du mercredi 12 septembre. — Meeting held on Wednesday, September 12th.

La séance est ouverte à 16.30 heures sous la présidence du Dr. R. L. Smith-Rose, Président de la sous-commission.

The President summarizes the decisions reached at Copenhagen in 1931, e. g. the recommendation of a loop instead of an open aerial, and refers to paper nº 50 (²) by R. A. Watson Watt and R. L. Smith-Rose, paper nº 17 (³) by C. R. Englund, and paper 23 (⁴) by P. E. Watson. He mentions as suitable subjects for discussion :

1. — Differences obtained when using different types of apparatus side by side.
2. — Standardization of methods and apparatus
3. — Accuracy to be aimed at.
4. — Type of receiver to use at wave lengths so short (15 metres) that the loop becomes unsuitable.

The President points out that discrepancies of the order of 20%, which are of common occurrence, seem unduly large for, at the frequencies concerned, current can be measured with a much higher accuracy.

(¹) Voir p. 108. (²) See p. 166.
(³) See p. 138. (⁴) See p. 141.

M. Espenschied thinks that, in view of the presence of noise, which is the other factor in determining the usefulness of the measurement, 10% is sufficient for the field strength determination.

M. R. A. Heising says that usually variations due to fading render uncertain the quantity to be measured to such an extend that accuracies greater than 10, or even 20 per cent, contribute nothing.

M. Kirke thinks that the object of the measurement should be borne in mind when discussing the accuracy. For short-waves signals, which vary considerably in intensity, 10% is adequate. It is sufficient also for measurements, at a given point, of the strength of medium-length waves from a broadcasting station. But if it is desired to study the distribution of power in the neighbourhood of a transmitter, a higher accuracy is necessary.

In recent measurements at 1500 metres, a vertical aerial has been found to give larger variations than a frame.

Dr. Dellinger agrees with M. Kirke that different degrees of accuracy are required in different circumstances, and says that agreement is necessary as regards the accuracy to be aimed at for different frequencies, different distances, and different times.

M. Watson Watt considers the accuracy now obtainable adequate for ordinary commercial and engineering problems, but not adequate for comparing the efficiency of aerials.

Dr. Jensen thinks also that 10% is not adequate for the latter purpose, but considers that much higher relative accuracies can actually be obtained.

Dr. Dellinger discussing the relative advantages of recording results by the absolute maximum, the 5% quasi-maximum, and the 50% mean methods, previously referred to by M. Watson Watt, prefers the quasi-maximum method for most purposes. The mean method does not give much useful information, especially with automatic recorders. The absolute maximum method seems the best for the comparison of characteristics at different frequencies. The results depend on the duration of the observations, but that can be specified for special cases.

M. Kirke agrees with Dr. Dellinger as to the advantages of the quasi-maximum method. His apparatus for the mean method records the value exceeded during half the time.

M. Jouaust déclare n'avoir pas rencontré de difficultés dans la mesure des intensités de champ des émetteurs de radiodiffusion. Les mesures furent effectuées pendant la journée et aucune grande variation ne fut observée.

The President sums up the discussion by saying that for certain types of engineering problems, 10% is adequate, but that other purposes demand higher accuracy. It seems very desirable that an apparatus of high accuracy be standardized for calibration and comparison of commercial apparatus.

La Sous-Commission décide à l'unanimité de présenter à l'approbation de la Commission I, les résolutions 1 et 2 (¹).

La Sous-Commission décide de tenir une nouvelle réunion le vendredi 14 septembre à 14.30 heures pour discuter la spécification des appareils étalons pour la mesure absolue de l'intensité du champ.

La séance est levée.

(¹) Voir p. 109.

Séance du vendredi 14 septembre. — Meeting held on Friday, September 14th.

La séance est ouverte à 14.30 heures, sous la présidence du Dr. R. L. SMITH-ROSE.

The President says that, according to the resolution taken at the previous meeting, that meeting is held to discuss the specification of standard apparatus for the absolute measurement of field strength.

Le *Prof. Jouaust* souligne l'urgence qu'il y a à effectuer des comparaisons internationales d'appareils standards devant être installés dans les laboratoires nationaux et dans les laboratoires les plus importants, et fait remarquer que les différentes méthodes d'en exprimer les résultats (maximum, quasi-maximum ou moyenne) ne sont pas une question scientifique mais commerciale qui ne concerne pas l'U. R. S. I.

La Sous-Commission est d'accord pour convenir que les appareils étalons devraient être munis d'une antenne en boucle pour les longueurs d'ondes dépassant 15 mètres, et d'un dipole pour les longueurs d'ondes inférieures à 15 mètres, mais elle estime que les connaissances actuelles ne justifient pas la spécification des dimensions, de la nature, du mode de couplage du dipole au récepteur ni de sa hauteur au-dessus du sol.

The President asks the views of the Sub-Commission on the advisability, in case of the loop, of specifying the height above the ground.

M. Barfield proposes that the apparatus be such as to yield the value of the field at the centre of the loop, wherever the loop is placed.

En suite de cette discussion, la Sous-Commission adopte à l'unanimité, le texte définitif des résolutions 4 et 5 (¹) à soumettre à l'approbation de la Commission I.

The President asks the opinion of the meeting on the specification of accuracies at various frequencies for the national standard apparatus contemplated.

Le *Prof. Jouaust* ne considère pas comme nécessaire de fixer l'exactitude des mesures aux différentes fréquences. Il pense qu'il vaudrait mieux demander l'exactitude la plus élevée possible.

Après cette discussion, on convient d'établir une table donnant une précision minimum pour différentes valeurs de la fréquence. La division des fréquences suggérée par le Président est adoptée et des chiffres provisoires sont fixés pour la précision.

Différents orateurs signalent que la précision que l'on pourrait atteindre, n'est pas indépendante de l'intensité du champ à mesurer.

After more discussion by Messrs. L. H. Bainbridge-Bell, R. H. Barfield, A. G. Jensen, E. H. Rayner and Wilson, it is resolved to discuss the matter further at another meeting, (to be held on Monday, September 17, at 11.30), and in the meantime to circulated the table (¹) to the members, asking them to suggest figures for the minimum and maximum field strengths to be measured, and for the accuracy to be specified in each case.

En ce qui concerne la seconde proposition de la communication de M. Jouaust, la Sous-Commission est d'accord pour déclarer que l'U. R. S. I. n'est pas intéressée dans l'appréciation des mérites relatifs des différentes méthodes pour déduire, d'un certain nombre d'observations, les valeurs moyennes, celles des quasi-maxima de champ variables dans le temps.

(¹) Voir p. 109.

(¹) See p. 109.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

La séance est ouverte à 11.30 heures, sous la présidence du Dr. R. L. Smith-Rose.

The President gives an account of the answers he has received to the questionnaire circulated to the members to ascertain their views on the figures to be specified for the standard apparatus contemplated.

Le *Prof. Jouaust* préfèrerait ne pas voir mentionner de chiffres, car il estime que les connaissances actuelles au sujet des précisions que l'on peut atteindre sont trop précaires. Il est partisan d'essayer d'atteindre la plus grande précision possible. Néanmoins, il adhérera à la spécification adoptée par la majorité des membres et dans la construction de l'appareil étalon préconisé, il s'efforcera de suivre la spécification.

On passe ensuite à la discussion des différents chiffres, et on adopte un tableau à soumettre à l'approbation de la Commission I, ce tableau est reproduit avec la résolution 3 (¹).

On examine ensuite la question de la hauteur effective des antennes.

Mr. L. H. Bainbridge-Bell thinks more detailed knowledge is required in order to pass from the field-strength, as measured with the standard apparatus, to the input to typical receivers using open aerials. The use of an open aerial on the assumption that the height is ralf the physical height gives results differing by 15-20% from measurements of the same field with a loop aerial.

Mr. E. H. Shaughnessy considers the further investigation of effective heights very desirable. The dipole may, at some future time, require a more complete specification, for which knowledge of effective heights would be essential.

Après une discussion à laquelle prennent part MM. L. H. Bainbridge-Bell, Eastham, R. Jouaust, A. J. Jensen, H. L. Kirke et E. H. Rayner, on examine et on adopte les résolutions à soumettre à la séance plénière de la Commission 1. (¹)

COMMISSION II. — PROPAGATION DES ONDES

COMMISSION II. — RADIO-WAVE PROPAGATION

INTRODUCTION

Les documents ci-après concernant la Commission II furent distribués avant l'Assemblée Générale : (²)

The following papers concerning Commission II were circulated before the General Assembly : (²)

N° 1. — Note sur l'Intérêt de Sondages Continus de l'Ionosphère par la Méthode des Radio-Echos, par M. A. Dauvillier.

N° 2. — Rapport du Comité National Français sur les Résultats du Trafic Commercial.

N° 3. — Report for the Commission on Radio-Wave Propagation, by Prof. Dr. Jhr. Elias.

N° 5. — Report on Radio-Wave Observations made at Angmassalik by the Dutch Expedition during the International Polar-Year, by J. A. de Bruine.

(¹) Voir p. 109. (²) Voir résumés, p. 120.

(¹) Voir p. 109. (²) See abstracts on p. 120.

N° 7. — Publications on Radio-Wave Propagation (Bibliography of the « Report on Radio Research in Japan »).

N° 8. — Publications relatives aux Recherches Radio-Electriques, par le Dr. J. Lugeon.

N° 9. — Programme of Ionosphere Measurements and Forms for Analyzing Data, by the Radio-Section of the Bureau of Standards.

N° 10. — Terrestrial Magnetism and its Relation to World Wide Short-Wave Communications, by Henry E. Hallborg.

N° 11. — Report on Long Distance Broadcasting Transmission (600-1500 kc. per sec.). Polarization of Broadcast Waves. Charts for Short Wave Transmission. Ultra-Short Wave Diffraction, by T. L. Eckersley.

N° 18. — Auxiliary Apparatus for Operating Kennelly-Heaviside Layer Height Recorders, by H. R. Mimno and Pao Ho Wang.

N° 19. — Analysis of a 6.000 Hour Record of Kennelly-Heaviside Layer Heights, by H. R. Mimno and Pao Ho Wang.

N° 25. — Memorandum on Sunspots, by J. C. Schelleng.

N° 26. — Distribution of Radiation in the Vertical Plane for Communication with Short Waves over Great Distances, by C. W. Latimer.

N° 27. — Report on Radio Reasearch in Japan, by the Japanese National Committee.

N° 28. — Measurements of the Heights of the Kennelly-Heaviside Layer in Japan, by T. Minohara and Y. Itô.

N° 29. — Field Strength Measurements and Directional Observations of Short Waves, by T. Nakai.

N° 30. — Field Strength Measurements and Directional Observations of High-Frequency Radio-Waves at the Electrotechnical Laboratory, Ministry of Communications, by T. Nakai.

N° 31. — On Directional Observations of Long-Distance Short-Wave Stations and the Relation between Directional Deviation and Scattering in the Ionosphere, by T. Nakai.

N° 32. — On the Transmission of Short-Waves through the North-Polar Night-Zone, by T. Nakai.

N° 35. — Ionospheric Measurements at Losap Island during the Solar Eclipse of February 14th, 1934, by K. Maeda.

N° 36. — Ionosphere Heights Measured in the South Seas Islands and Radio Observations made during the Solar Eclipse of February 14th, 1934, by T. Minohara and Y. Irô.

N° 37. — Summary of some Theoretical Contributions to the Problem of Propagation of Radio Waves over the Earth, by Dr. B. van der Pol and Dr. K. F. Niesen.

N° 45. — Measurement of Ionosphere Layer Heights and Correlation with other Geophysical and Cosmic Data, by Prof. E. V. Appleton.

N° 46. — Report of the British National Committee on Investigations on the Propagation of Waves carried out in Great-Britain from April 1931 to June 1934.

N° 53. — An Analysis of Continuous Records of Field Intensity at Broadcast Frequencies, by S. S. Kirby, K. A. Norton and G. H. Lester.

N° 56. — Report on Ionization Changes during a Solar Eclipse by E. V. Appleton and L. Chapman.

N° 57. — Rapport sur les Recherches Relatives à la Propagation des Ondes Radio-Electriques Courtes Entreprises pendant l'Année Polaire, par R. Jouaust, R. Bureau et J. Habert.

Nº 58. — Rapport sur les Recherches Relatives aux Atmosphériques Entreprises pendant l'Année Polaire, par R. Bureau, R. Failletaz et J. Habert.

Nº 59. — Sur la Comparaison de quelques Courbes de la Variation Diurne des Atmosphériques, par R. Failletaz.

Nº 60. — Etude des Courbes d'Enregistrement d'Atmosphériques au Scoreby Sund par R. Bureau.

Nº 62. — Interaction of Radio-Waves, by B. van der Pol and J. van der Mark.

Nº 65. — Note sur la Propagation des Ondes de 18,68 et 31,19 m., sur le parcours Saïgon-Paris.

Nº 66. — Note sur la Propagation des Ondes de 24,56 et 33 m. entre Paris et Alger.

Nº 67. — Beziehungen zwischen Wellenausbreitung und Echos zu anderen Geophysikalischen Erscheinungen, K. W. Wagner und K. Fränz.

Séance d'ouverture du mercredi 12 septembre.

Opening Meeting held on Wednesday, September 12th.

La séance est ouverte sous la présidence de M. le Dr. J. H. DELLINGER, Président de la Commission II.

The President. — The first duty in this Commission is the sad one of recording the death of its leader. Dr. Austin was President of Commission II for many years, as well as having been for a short time President of the U. R. S. I. and for a long time Chairman of the American National Committee.

I was nominated by the Executive Committee to carry on his work. I have not prepared a summary of the field as Dr. Rayner did for his Commission.

My idea as to what we had better do this morning would be to summarize the subjects to be discussed in Commission II, and then consider what sub-commissions would be desirable, and then allocate the papers of which a good many are appropriate for sub-commissions. If you have with you the list of subjects proposed for discussion in the various Commissions (¹) and the list of papers available (²), which have been prepared by the Secretariat, it would be useful if you would have them before you.

Of the subjects proposed for discussion in Commission II, the five first were set up by the Copenhagen meeting three years ago, and I added some others on the basis of material that seemed to be available for discussion.

The President then reads the list of subjects, and goes on :

So far as I have observed there are no papers on the item « Variations of wave direction and polarization ». We will omit that subject unless material shows up in that field, and in its place I propose to insert a topic on which a paper has appeared for our consideration and which does not seem to fit any of the other subjects : « Interaction of radio waves » (¹), a paper submitted by Dr. van der Pol and J. Van de Mark.

As you already know, we contemplate a sub-commission on Ionosphere Measurements, proposed by Prof. Appleton in accordance with correspondence circulated before the meeting, so we can consider it settled that Ionosphere Measurements will be considered in a sub-commission and reported to the Commission latter.

The subject of the Polar Year is also listed under this Commission, but it was really a sort of special Commission set up by the Copenhagen meeting. It will be the subject of Friday's deliberations.

One of the subjects of very considerable interest amongst those listed is that of eclipses, and we have for consideration the results of work on recent eclipses, and should also do something about the organization of future

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(¹) See p. 13. (²) See p. 32.

(¹) Document nº 62.

work. There is an eclipse in 1937, concerning which we have some suggestions in one paper before us, so a sub-commission on eclipses would be worth while to consider the subject and possible suggestions for future work.

The subject of Dr. van der Pol's paper on the interaction of radio waves might well be considered in one of the other sub-commissions, as also in that case it might seem desirable to consider a programme for future work and possible international co-operation.

Other subjects which have occured to me as possibly being suitable for handling by sub-commissions are those of propagation data resulting from commercial radio traffic, long-delay echoes, received wave intensities as a function of frequency, time, etc., and ionosphere propagation analysis. I think that before deciding definitely on whether any such sub-commissions should actually be set up it would be well to examine the titles of papers available. As this is a business session, we shall run through the list of papers which are available for Commission II (¹) and, since they have been numbered, it will be convenient to allocate them to the various subjects on agenda.

The President then indicates the grouping of the numbered papers by subjects, and goes on :

— I would now like to inquire what additional papers anyone may have to offer for the consideration of Commission II.

M. Picault prend alors la parole pour présenter à la Commission une « Note sur la Propagation des Ondes de 24, 56 et 33 mètres entre Paris et Alger » (²) et une « Note sur la Propagation des Ondes de 18, 68 et 31,19 mètres sur le parcours Saïgon-Paris » (³), toutes deux établies par le Service de la T. S. F. français.

Le *Prof. Wagner* prend ensuite la parole pour présenter une étude sur les relations existant entre les phénomènes des radio-échos et la propagation, et sur d'autres phénomènes terrestres (¹). Cette étude est basée sur un travail entrepris au cours d'une expédition en Norvège et il exprime le désir de proposer l'examen de ce rapport dans la sous-commission intéressée.

The President. — The question has been asked to as whether a report by Dr. Eckersley on long-distance transmission is available. That is document No. 11 in the list, but copies have not yet been distributed; I understand that it is expected that enough copies will be here for distribution during the meeting, in the same way as the Japanese Report.

I am informed that the one page paper, a general remark on propagation by Prof. Manneback of Louvain, will be offered. We also have « Seasonal Variations in the Ionosphere » from the U. S. A. by J. P. Straffer of the Bell Telephone Laboratories ; « Method of Sounding by Atmospheric Disturbances » by Dr. Lugeon ; « The relation of the Pacific Eclipse of June 8th, 1937, to investigations of changes of ionization of the ionosphere » by Berkner of the Carnegie Institutions of Washington. I find that we do not have listed any paper under « Long-delay echoes ». That subject was put on the agenda by the Copenhagen Conference. I would like to ask Prof. Appleton to report on the present status of the subject.

Prof. Appleton. — I could give a report in three lines. The experiments have been carried on with the help of the B. B. C. for three months, and so far as I can see there has been no absolutely indisputable evidence obtained of the existence of long-delay echoes.

The President. — Thank you for the statement of the case. We might as well dispose of this subject at this time. Has anyone else anything to offer, positive or negative, in long-delay echoes ?

Aucune réponse n'est faite à cette question du Président.

(¹) See p. 32.
(²) Document nº 65. (³) Document nº 66.

(¹) Document nº 67.

The President. — I would like to say that the initiative of the British autorities in undertaking a wide-spread investigation of this, having a great many people listening for these long-delay echoes in many parts of the world, deserves our compliments. We hope that in the course of time this work will lead to something definite, so that we shall know the facts. It is interesting that very little has developped in this field since the original discovery of the long-delay echoes several years ago.

Le *Dr. Lugeon* présente ses *Tables Crépusculaires* donnant l'altitude au zénith des rayons rasants du Soleil pour toutes les latitudes de degré en degré. Cet ouvrage de 438 pages est édité par l'Institut National Météorologique de Pologne, à Varsovie. Il sera utile pour les études de propagation, puisqu'il donne à tout instant la position des rayons du Soleil dans l'atmosphère pour toute la Terre et permet de calculer également le lever et le coucher sans difficulté.

The President. — This book of Dr. Lugeon on Sunset Tables is very useful in work on ionosphere measurements, and is well worth the consideration of those concerned. I hope you will all examine it and make further mention of it in sub-commission meetings.

The paper not handled in sub-commissions will be considered in the full session of Commission II. I would like to ask the members of the French National Committee whether they think it desirable to have a sub-commission on the subject of the results of radio traffic which is treated in Document No. 2, the French National Committee report. Do you wish any consideration of that by a sub-commission, or shall we simply consider that in the main session ?

Prof. Jouaust. — Je crois qu'il est préférable d'examiner le Rapport du Comité National Français sur les résultats du trafic commercial au cours d'une séance plénière de la Commission.

The President. — Let us summarize the status of the sub-commissions, and also please be thinking of what sub-commissions any of you would care to serve on, or other persons that you would care to suggest to serve on them.

Les sous-commissions seront constituées comme suit :

1. — Mesures de l'Ionosphère : MM. Prof. Appleton (Président), Prof. Dr. Jhr. Elias, T. L. Eckersley, Dr. Heising, Prof. Manneback, Prof. Mimno, R. Naismith, Prof. Dr. Wagner.

2. — Taches Solaires : MM. Dr. Heising (Président), Commandant Bureau, Lt. de Vaisseau Habert, Namba, Prof. Yagi, Watson-Watt.

3. — Action Réciproque des Ondes : MM. Dr. van der Pol (Président), Prof. Appleton, T. L. Eckersley, Dr. Espenchied, Kirke, Prof. Manneback, Prof. Mesny, Prof. Dr. Wagner, Watson-Watt.

4. — Eclipses : MM. Prof. Chapman (Président), Dr. Espenchied, Prof. Jouaust, Dr. White, Prof. Yagi.

5. — Théorie de la Propagation dans l'Ionosphère (Sous-Commission commune aux Commissions II et IV) : MM. T. L. Eckersley (Président), Prof. Dr. Jhr. Elias, Prof. Manneback, Namba, Dr. van der Pol, Prof. Dr. Wagner.

The President. — The membership of the sub-commissions is not exclusive at all. We have such a crowded programme, and so little time remains for the sub-commissions' work, and we have now already so many sub-commissions that I think it is going to be quite impossible to hold all sub-commissions at independant times. I suggest that each sub-commission chairman gets his commission together when he can and do the work, avoiding sessions of the main Commissions if possible. Also, will all delegates please feel free to attend any sub-commission's meetings. It will be the responsability of each sub-commission's chairman to notify all members of his sub-commission. Annoucement of meetings of sub-commissions will be given on the bulletin board.

M. Watson-Watt. — The British National Committee is anxious to place at the disposal of these sub-commissions the assistance of their associates in this country. Particularly there are available for help to these commissions, members of the staff of the Electricity and Radio Departements of the National Physical Laboratory. Dr. Rayner and I would be happy to arrange that our colleagues in these Departments should serve on the sub-commissions at the desire of the Chairman.

The President. — I think there should be a definite reporter for each sub-commission. Will your associates in the N. P. L. be available to serve as reporters ?

M. Watson-Watt. — Yes, they will.

The President. — I would suggest that each sub-commission's Chairman sees M. Watson-Watt with a view to having someone as a reporter for each meeting of his sub-commission. I wish to thank you for your help in these intricate arrangements. I think our Commission is well started for a profitable session.

Séance plénière du mardi 18 septembre.

Full Meeting, held on Tuesday, September 18th.

La séance est ouverte à 14.30 heures, sous la présidence du Dr. J. H. DELLINGER, Président de la Commission II, assisté du Dr. R. L. Smith-Rose, comme Rapporteur.

The President opens the meeting by stating that the papers submitted for discussion at the full meeting of the Commission will be presented in accordance with the agenda circulated.

1. — PRESENTATION DES DOCUMENTS :

a) Le *document n^o* 2 « Rapport du Comité Français sur les résultats du trafic » (¹), est lu par le *Prof. Jouaust.*

The President states that it would be useful to pursue this matter, in order to determine whether the results from the communication traffic would lead to useful scientific data.

Dr. van der Pol offers a selection of graphs showing the varying results obtained in communication traffic between Holland and the Dutch East Indies at different times of the day.

(b) Paper No. 37 « Summary of some theoretical contributions to the problem of propagation of radio waves over the earth » (²), is summarised by *Dr. van der Pol.*

Prof. Elias enquires if consideration of the surface wave of Prof. Sommerfeld's analysis is included in the present work.

Dr. van der Pol replies that the distinction of surface and space waves in Sommerfeld's work is one of defining the limits within which the integration of a now simple function is carried out. In the work described in Paper No. 37, a simpler and probably more accurate solution is obtained of the propagation of waves along the earth's surface.

c) Paper No. 11 « Report on long distance broadcasting transmission (600-1500 kc/sec.) etc. » (¹) is presented by *M. T. L. Eckersley.* — This deals with *(a)* the extension of the range of the Madrid curves indicating the relation between field intensity and distance, *(b)* the description of a radio polarimeter for determining the direction of polarisation of downcoming waves, and *(c)* the theoretical modification of Watson's diffraction formula and its comparison with experimental results obtained on medium and ultra-short waves.

(d) Paper No. 53 « An analysis of continuous records of field intensity at broadcast frequencies » (²) read by *Dr. Dellinger.* This paper

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(¹) Voir p. 120.
(²) See p. 148.

(¹) See p. 135. (²) See p. 183.

analyses the results of measurement of the field intensities of several American broadcasting stations. Among the several conclusions are : that the received nights field intensities are frequently greater than the inverse distance value; that they have maximum values at about 600 km ; and that sky-wave radiation is in many circumstames important in the daytime at distances greater than 600 km.

Some discussion takes place between *Dr. van der Pol* and *M. T. L. Eckersley* as to whether the correct law should be compared with the inverse distance or not, but this is not clear at present, and the physical explanation of the results is lacking.

M^r. Eckersley points out that the magneto-ionic theory indicates that transmission in a direction perpendicular to the earth's magnetic field is found to be easier than in a direction parallel to the field.

(e) Le *document n°* 65 « Note sur la propagation des ondes 18.68 et 31.19 m. sur le parcours Saïgon-Paris (Service de T. S. F.) » est présenté par *M. Picault.* Cette étude décrit les résultats d'observations d'échos pour des signaux captés dans l'exploitation du service signalé dans le titre. A certaines époques de l'hiver, ces échos durent environ 1 ½ heures et présentent un retard de 0.07 sec.

Le *Prof. Jouaust* déclare qu'il a utilisé ces signaux pour déterminer la vitesse de propagation qui semble être légèrement inférieure à celle de la lumière. — Il a constaté que d'un jour à l'autre, les variations de la durée de la propagation étaient plus grandes que les erreurs de mesures.

M. Picault en réponse à une question posée par M. Matteini, déclare que la présence des échos et les difficultés de communication dues au fading ont considérablement diminué et qu'ils ont cessé d'être gênants, ce qui a coïncidé avec l'installation en 1932, de systèmes de réflecteurs à Saïgon.

(f) Le *document n°* 66 « Note sur la propagation des ondes de 24, 56 et 33 m. entre Paris et Alger (Service de la T. S. F.) » est également présenté par *M. Picault.* Cette étude décrit un phénomène d'évanouissement (fading) sélectif, observé sur la communication téléphonique Paris-Alger. Ce fading sélectif affecte successivement les diverses fréquences de la bande modulée.

The President express a wish that M. Picault may be able to publish the interesting results included in these two papers.

(g) Paper No. 10 on « Terrestrial magnetism and its relation to world-wide short-wave communications » (¹), is read by *M. Briggs.*

The paper deals in some detail with the effect of variations in the earth's magnetic field on the reliability of radio communications. The extent of the disturbance caused to various radio circuits is considered in relation to the intensity of magnetic activity.

Prof. Chapman enquires if the diagrams accompanying the paper are centred on the earth's north magnetic pole, or the centre of magnetic activity, coinciding approximately with the pole of the earth' magnetic axis. It appears to him that the diagrams need geographical correction on this point, the apparent discrepancy in some cases being about 10°.

M^r. Briggs thinks that M. Hallborg (the author of the paper) has used the magnetic pole as the centre. While he appreciates Prof. Chapman's point, he does not think the overall accuracy of the communications aspect of the problem is sufficient to require the proposed correction.

The President refers to the importance of continuing the study of the effect of magnetic activity on radio communication.

(h) Paper No. 26 « Distribution of radiation in the vertical plane for communication with short waves over great distances » is also presented by *M. Briggs.*

(¹) See p. 135.

This paper describes three methods of determining the angle of projection from a radio transmitter in order to ascertain the optimum angle for any communication circuit.

Le *Dr. Lugeon* demande quel est l'angle moyen d'arrivée des signaux à un récepteur de 30.000 kc/sec. de fréquence.

Dr. Smith-Rose draws attention to the results of British work on this subject. Dr. Walmsley(¹) has measured the best angle of projection from the Rugby station for several radio channels to America and Europe; while M. Wilkins (²) has measured the angle of reception in England of signals from America transmitting stations.

2. — RESOLUTIONS :

La Commission reçoit ensuite et approuve une série de résolutions présentées par les Présidents des Sous-Commissions, comme il en est rendu compte plus bas.

Le *Prof. Jouaust* demande qu'après approbation, toutes les résolutions soient traduites en français.

a) Sous-Commission de l'Année Polaire Internationale (³).

The two resolutions put forward by *Prof. Appleton,* President of this sub-commission are adopted. A third has been proposed by *M. Watson-Watt* relating to the continued existence of the sub-commission, but *Prof. Appleton* express the opinion that a permanent sub-commission to be proposed by the Ionospheric Measurements sub-commission would meet this purpose. This is agreed to.

b) Sous-Commission 1. — *Mesures de l'Ionosphère* (³).

Ten resolutions are presented from this sub-commission by the President, *Prof. Appleton.* After a few verbal alterations, these are adopted.

Conformément à la résolution n° 10, on nomme une *sous-commission permanente des Mesures de l'Ionosphère,* elle est constituée comme suit : Prof. E. V. Appleton (Président), Commandant R. Bureau, Dr. J. H. Dellinger, Dr. D. B. la Cour, M. R. Naismith, Dr. B. van der Pol, M. R. A. Watson-Watt.

Le Président a le pouvoir de désigner des représentants d'autres pays s'il le juge nécessaire.

c) Sous-Commission des Taches Solaires (¹).

Dr. Heising, President of this sub-commission presents the two resolutions which are adopted.

d) Sous-Commission 3. — *Action Réciproque des Ondes (²).*

Dr. van der Pol, the President, gives a brief report of the work of this sub-commission, and puts forward the resolution, which is adopted.

e) Sous-Commission 4. — *Eclipses (²).*

The President of this sub-commission is *Prof. Chapman*; the four resolutions proposed are adopted.

3. — REMERCIEMENTS :

Dr. Dellinger in concluding the meeting, express the gratitude of Commission II to the authors of papers presented, and to the Members of all sub-commissions, and to the General Secretariat and the rapporteurs and the British National Committee for all the assistance they have rendered to the work of the Commission. He also acknowledges the patience of the French-speaking members and thanks M. P. Vigoureux for his services as interpreter.

(¹) *Journal Inst. Elect. Eng.*, 1934, vol. 74, p. 543.
(²) *Idem*, p. 582.
(³) Voir p. 110.

(¹) Voir p. 113.
(²) Voir p. 114.

Séance de clôture du mercredi 19 septembre.

Final Meeting held on Wednesday, September 19th.

La séance est ouverte à 11 heures, sous la présidence du Dr. R. L. Smith-Rose.

The Chairman. — Dr. Dellinger infortunately is not able to be here this morning, so I am deputising for him as President of Commission II.

You will recall that we had a full meeting of Commission II yesterday afternoon, and we adopted all the resolutions which came to the Commission from the various sub-commissions. One or two minor amendments were made to the typescript as circulated, but I do not propose to read the resolutions again.

We have then to pass on to a resolution which comes from the sub-commission appointed jointly by this Commission and Commission V. That resolution has abready been before Commission V this morning and has been adopted. Merely as a formality I put before you, nº 5 of the resolutions coming from Commission V (¹).

Then I have a further resolution which has just come before me, which is proposed by Prof. Appleton (²).

Après discussion, une légère modification est apportée à la résolution présentée par la Sous-Commission commune aux Commissions II, et V (³) et cette résolution est adoptée.

The Chairman. — That completes our business. I have to thank all those who have assisted in the work of this Commission, the Chairmen and Members of the various Sub-Commissions, and the reporters.

Sous-Commission de l'Année Polaire

Polar Year Sub-Commission

Première Séance du vendredi 14 septembre.

First Meeting held on Friday, September 14th.

La séance est ouverte à 9.45 heures, sous la présidence du Prof. E. V. Appleton, Président de la Sous-Commission, assisté de M. R. Naismith comme Rapporteur.

The President opens the discussion on the work carried out under the auspices of the Union during the International Polar Year 1932-1933.

In view of the late arrival of some of the documents, it was not possible to present a comprehensive statement of all the work which has been done. Instead members are given a document (¹) which classifies the work done during the Polar Year under three headings, viz. observations in high latitudes, observations in temperate latitudes and observations in low latitudes, and a document (⁴) containing a number of papers on work done immediately after the Polar Year. Rapid improvements in technics during the Polar Year have resulted in more useful observations being made at the end of the period than were possible at the beginning, and it is therefore suggested that the discussion on the Polar Year of 1932-1933 should include the observations which were made immediately after the Polar Year.

The President then introduces the subject of the International Polar Year, explaining the aims and the results of the first Polar Year

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(¹) See Annexe I, p. 42.

(¹) See p. 119. (²) See p. 115.

(³) Voir p. 119. (⁴) See Annexe II, p. 43.

and the organization of the second, suggesting also that the documents relating to the programme of Radio Observations to be made during the Polar Year should be preserved in the Archives of the Union.

He then gives an account of the work carried out by the British Expedition at Tromsö (Latitude 69 ½°) in connection with the International Programme and proceeds to discuss the results obtained. These may be summarised as follows :

(a) The ionization produced by the ultra-violet light from the sun in region E at Tromsö is only 60% of that produced in latitude 52 ½°. The observations refer to the equinoxes. He shows that this is in agreement with the results obtained in Canada and America during the eclipse of the sun on August 31st, 1932, and concludes that the normal ionising agency for region E at any rate is the ultra-violet light from the sun.

(b) During periods of intense magnetic activity no energy is returned from the Ionosphere.

The President refers to the description and interpretation of these results published in « Nature » and then proceeds to give a short account of the work done by Russia.

RUSSIE.

The work was carried out at Murmansk, Lat. 68° 56' N. long. 33° 05' E. and was confined to the last 3 months of the Polar Year. The results obtained agree with those of the British Expedition concerning the correlation of magnetic activity and absence of echoes. Echoes were at times observed from heights as low as 65 kms. and Prof. Bontch-Brouewitch records that an « absorbing layer » was produced at times at a height less than 65 kms.

The President then calls on Prof. Wagner to give an account of the work carried out by Germany during the Polar Year.

ALLEMAGNE.

The observations were made at Tromsö in collaboration with the British party during the Polar Year, but were continued for a second year on account of their importance.

Prof. Wagner refers to four curves which show respectively (1) the variations of magnetic activity, (2) variations in reflecting power of the Ionosphere, (3) variations of the field strength obtained from Breslau $\lambda = 325$ m., and (4) variations of the direction of arrival of the waves from Breslau. These curves were plotted for the months January-June and show the inverse correlation of (1) with (2) and the direct correlation of (3) and (4) with (2). Curve (3), also shows the gradual reduction of field strenght as the summer season advanced.

Prof. Wagner refers to a paper by Dr. Mögel from which he infer red that observations made on commercial long-distance radio telegraphy during the period 1927-34 showed a decrease in the amount of ionisation with decreasing solar activity and drew a parallel with the echo measurements made at vertical incidence.

In opening the discussion which followed, *the President* suggests that Curve 4 (which shows the disappearance of directional error when magnetic activity is high) may be due to the fact that the rays which arrive at the receiver at a small angle of incidence (and which therefore contribute most to the directional error) are not reflected during a magnetic storm, and this provides a complete explanation of this very interesting result.

Prof. Wagner agrees with this explanation.

Le *Dr. Lugeon* décrit le résultat des dépouillements des enregistrements d'atmosphériques qu'il a effectués à Bear-Island et à Tromsö pendant toute l'Année Polaire (¹). Les théories émises antérieurement sur le sondage par les parasites ont été entièrement confirmées. Des aurores polaires basses sur l'horizon forment un écran absorbant les rayons électromagnétiques parasites issus du même azimut. Affaiblissement

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(¹) *C. R. Paris*, t. 195, p. 817, 1932 ; t. 198, p. 1712, 1934 ; t. 199, p. 1059, 1934.

parasites américains émanant du SW après 22 h., lorsqu'une aurore obture l'horizon SW, jusqu'à quelques degrés d'altitude. Ce fait concorde avec la disparition des échos de Tromsö, signalée par le Prof. Wgner.

The President replies that these observations give additional proof that the atmospherics come from the south.

Mr. Eckersley refers to the susceptibility to small magnetic disturbances of waves arriving at small angles of incidence and the immunity of the long-distance signals which presumably arrive at greater angles of incidence. It is difficult to explain how absorption below E region should not affect the lower angle trajectories to a greater extent than the vertical ones.

Le *Lieutenant Habert* montre l'importance de la tendance à la récurrence tous les 27 jours de l'activité magnétique, cette tendance a été constatée dans toutes ses mesures.

The President then calls on Professor Elias to give an account of the work done by Holland during the Polar Year.

HOLLANDE.

Prof. Elias describes the arrangements which have been made to send an expedition to Angmagssalik (Latitude 65 ½°) and the programme carried out there. The results may be summarized as follows :

1. The number of echoes reached a maximum in May and June.
2. The number of echoes obtained throughout the day reached a maximum between 1800-2000 A. M. T.
3. 100 km. was the minimum height from which echoes were observed.
4. The maximum number of echoes were observed between 100-200 km. and between 300-400 km.

He concludes that the main ionised region is due to charged particles and provides a theory to account for the magnetic observations made by members of the expedition to Greenland.

Dr. van der Pol, who opens the discussion, emphasises the fact that the radio measurements were all made by one man, M. de Bruïne, a pupil of Prof. Elias, who also prepared the report.

Mr. T. L. Eckersley refers to the maximum number of echoes occuring at 1800-2000 at the time of magnetic maximum which appears to contrast with the results discussed in the other papers.

The President replies that he thinks the explanation lays in the fact that it is the after-effects of the storm which cause the trouble, and refers to his statement that an increase of ionization is frequently observed at the beginning of a magnetic storm.

FRANCE.

Le *Lieutenant Habert* donne un court aperçu des travaux de l'Expédition Française à Scoresby Sound (Latitude 70½° N); il décrit quelques-unes des difficultés rencontrées par l'expédition. Des observations ont été effectuées pendant Mai et Juin 1933 sur des fréquences entre 6 et 12 Mc/s, mais on n'observa pas d'échos.

The President suggests that these high frequencies may have penetrated both regions.

Le *Lieutenant Habert* répond que des échos furent obtenus à Paris sur ces fréquences.

The President at this point intimates a small change in the programme to allow Dr. Hafstad some time to consider the presentation of the American report from Alaska, which has just arrived. It is therefore proposed meantime to pass on to the work done in temperate latitudes.

JAPON.

Prof. Yagi gives a resume of the work done in Japan. He refers to the two reports published in « Radio Research in Japan » (1), where the results are shown in graphical form. It has not been possible to arrive at definite conclusions regarding these observations. He shows the effect of the Leonid meteor shower in November 1932 when the usual number of 4 or 5 echoes was increased to over 20.

AMERIQUE.

Dr. Jensen gives a report of the observations made in America by the Bell Telephone Laboratories. The observations were made at Deal (Latitude 40°). The lowest heights observed are 80-85 km. Measurements of equivalent height and earth potential were compared but no correlation could be shown. Critical frequencies at noon for $f^x_{F_2}$, $f^o_{F_1}$ and $f^o_{E_1}$ were plotted from March 1933 - April 1934. $f^x_{F_2}$ curve is a minimum in summer while $f^o_{E_1}$ is a maximum. $f^o_{F_1}$ shows a direct correlation with values of the earth potential. Measurements made during the Leonid meteor shower, referred to by Prof. Yagi, show increased ionization coinciding with the apparearance of meteors of the first magnitude.

Dr. Jensen then deals with the observations made by the Bureau of Standards at Washington (Latitude 39°). Curves showing the time of appareance and disappearance of echoes on 4.1 Mc/s. are compared with the times of sunrise and sunset on the ground and are found to be in good agreement during winter but not so good in summer. He then refers to a magnetic storm on 24 th. February 1933, when no echoes were observed from 1613-1619 U. S. T. on 4.1 Mc/s. A contour map illustrating the diurnal variation of critical frequency throughout the year is shown. This indicates the appearance of two minima during the night in the winter. A curve showing the critical frequencies for E region compared with $\sqrt[4]{\cos \psi}$, where ψ is the zenith angle of the sun is appended to the Bureau of Standards report.

The President comments upon the close relationship of f_{F_1} and earth potentials and refers to the comparison of the $f^x_{F_2}$, $f^o_{F_1}$, $f^o_{E_1}$ curves where $f^o_{E_1}$ shows a seasonal variation from a maximum in summer to a minimum in winter, $f^o_{F_1}$ also shows this variation to a lesser degree and $f^x_{F_2}$ not at all, which agrees with observations in England. This points to an influence increasing with height and suggests a seasonal variation of temperature which increases with height.

M^r. Eckersley states that from measurements of skip-distance phenomena, f_{F_2} is greater in summer than in winter, in the ratio 1.9. This maximum occurs 1 to 1½ hours after noon.

The President refers to some skip-distance measurements made some years ago in America by Dr. Dellinger which gave the value of 1.8.

This close agreement rules out latitude as the explanation.

Dr. Hafstad refers to a discussion on this subject in a Bureau of Standards publication in which f_{F_2} is shown to vary from year to year.

Dr. Hafstad then makes a brief reference to a report by Maris concerning the Polar Year observations made by the American expedition but which has not been received by the URSI. He goes on to refer to measurements made by Prof. Mimno at Harvard (Latitude 45 ½°) showing a minimum number of reflections from the E region at noon, which is attributed to increased absorption at that time. Another graph shows the height of F_2 to be greatest at noon, this being ascribed to absorption of the ray as it passes through the E region.

Le séance est levée.

ANNEXE I

Observations aux latitudes élevées

Allemagne :

Vorlanfige Ergebrisse der Funktechnischen Expedition der Heinrich-Hertz-Gesellschaft nach Tromsö (Norwegen), Prof. Dr. K. W. Wagner (1).

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(1) Papers n° 7 and 27.

(1) Sonderausgabe aus den Sitzungsberichten des Preussischen Akademie der Wissenschaften Phys.-Math. Klasse XXXII, Fev. 34.

Amérique :

The Work of the Polar Year Expedition to College-Fairbanks Station, Alaska, by H. B. Maris.

Analysis of a 6000-hour Record of Kennelly-Heaviside Layer Heights, by Prof. H. R. Mimno (1)

France :

Quelques observations sur la Propagation pendant l'Année Polaire au Scoresby Sund, par le Lieut. de Vaisseau Douguet (2).

Grande-Bretagne :

Ionospheric Investigations in High Latitudes, by E. V. Appleton, R. Naismith and G. Builder (3).

Radio Observations during the International Polar Year 1932-1933, by E. V. Appleton (4).

Hollande :

Report of Radio Wave Observations made at Angmagssalik by the Dutch Expedition during the International Polar Year 1932-1933, by J. A. de Bruine (5).

Russie :

Ionospheric Measurements in the Polar Regions, by M. A. Bontch-Bruewitch (6).

Observations aux latitudes moyennes

Amérique :

Report of Ionospheric Measurements during the Polar Year 1932-1933 at the Bell Telephone Laboratories, Deal, N. J. (Lat. 40°15′ N ; Long. 77°4′ W).

Polar Year Report of the National Bureau of Standards, Washington (Lat. 38°55′ N ; Long. 77°4′ W).

Japon :

Measurements of Heights of the Kennelly-Heaviside Layer in Japan from Aug. 1932 to Jan. 1933 (Tokyo, Lat. 35°40′ N ; Long. 138°45′ E), by T. Minohara and Y. Itô.

Observations aux latitudes basses

Indes :

Report on Mesasurements of Ionospheric Heights at Calcutta (Lat. 22°33′ N ; Long. 88°22′ E), by Dr. H. Rakshit.

Outre ces documents, d'autres études concernant les mesures de l'ionosphère effectuées immédiatement après l'Année Polaire, ont été reçues.

Observations aux latitudes élevées

Amérique :

Report on Ionospheric Investigations conducted at College-Fairbanks, Alaska, during the Winter 1933-1934 (Lat. 64°59′ N ; Long. 148°10′ W), by G. A. Fleming (1).

Observations aux latitudes basses

Amérique :

Report on Measurements obtained at the Huancayo Magnetic Observatory (Peru) following the programme of the Second International Polar Year during May to August 1933 (Lat. 12°3′ S ; Long. 75°20′ W), by H. W. Wells (1).

F-region Ionosphere Investigations at Low Latitudes, by L. V. Berkner and H. W. Wells (1).

Critical Frequency Observations of the E-layer at the Huancayo Magnetic Observatory, by H. M. Wells (1).

Italie :

Ionospheric Investigations in Low Latitudes (Lat. 15°20′ N ; Long. 38°55′ E), by I. Ranzi (2).

Ricerche sulle Condizioni della Ionosfera in Vicinanza dell' Equatore, I. Ranzi (3).

ANNEXE II

France :

Rapport sur les Recherches relatives à la Propagation des Ondes Radioélectriques courtes entreprises pendant l'Année Polaire, par R. Jouaust, R. Bureau et J. Habert (4).

Rapport sur les Recherches relatives aux Atmosphériques entreprises pendant l'Année Polaire, par R. Bureau, R. Failletaz et J. Habert (5).

Etude des Courbes d'Enregistrement d'Atmosphériques au Scoresby-Sund, par R. Bureau (6).

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(1) Document No. 19, see p. 139.
(2) *Onde Electrique*, vol. 13, n° 151, juil. 34.
(3) *Nature*, Sept. 2, 1933.
(4) *Proc. Roy. Inst.*, Oct. 27, 1933.
(5) Document No. 5, see p. 132.
(6) *Nature*, Feb.3, 1934.

(1) Department of Terrestrial Magnetism of the Carnegie Institution of Washington.
(2) *Nature*, Jan. 6, 1934.
(3) *Consiglio Nazionale delle Ricerche*, Maggio, 1934, XII.
(4) Document n° 57, voir p. 189.
(5) Doucment n° 58, voir p. 189.
(6) Document n° 60.

Deuxième Séance du vendredi 14 septembre.

Second Meeting held on Friday, September 14th.

La séance est ouverte sous la présidence du Prof. E. V. APPLETON, assisté de M. R. Naismith comme Rapporteur.

INDES.

The President gives an account of the observations made in India during the Polar Year. He refers to the low height of 75-80 km. for E region and says this was due to the geographical position of India. The ionization gradient is steeper in E region than in F. There appears to be a sudden drop in height between 1700 and 2100 with a corresponding increase in the strength of the echoes, due probably to the evening concentration of ionization which is supposed to occur after sunset.

AMERIQUE.

Dr. Hafstad gives an account of the work being done in Alaska in continuance of the Polar Year expedition there. Very few echoes were normally observed during the night-time so that it is difficult to make a useful comparison with magnetic activity. Curves were plotted to show the times at which echoes were observed and these were compared with the times of sunset and sunrise. The discrepancy between the observed curves and the curves of sunset and sunrise, on the earth's surface at various heights, is shown to be due to the fact that the ionization was produced at a certain height above the absorbing atmosphere of the earth.

ITALIE.

The President intimates that this concludes the work done in high latitudes and passes on to that done in low latitudes. He then proceeds to summarise the results obtained by Ranzi in Latitude 15° where it was observed that the maximum ionization for region E was reached at noon but for F_2 it was not reached till 1800. A subsidiary maximum occured at 0200. The occurence of abnormal E reflections was associated with thunderstorms as suggested by C. T. R. Wilson. Another observation was that of a type of « rustling » atmospheric which occured in the evening.

PEROU.

Dr. Hafstad then gives outline of the work done at Huancayo (Latitude 12° S), and refers to three papers. The first contains the results made at noon and midnight on 4 Mc/s., hourly measurements on the frequency and noon values of f_{E_1} and f_{F_2}. The second shows that the equivalent height of E region is about 100 kms. and the F region 200 kms. M. Berkener, who has directed these observations, proposes a method of presenting a multitude of data by means of isoionic curves. The growth of the F_1 region is clearly shown in the graphs. The measurement of f_{F_2} is less definite since the true values may have been masked by absorption. The quantity $f^x_{F_2}$-$f^o_{F_2}$ is found to be constant. The diurnal variation of f_{F_2} reveals two maxima, one at 1000 and the other at 1400, with a minimum at noon, showing that there must be other effects besides ultra-violet light from the sun present. Other curves show that in going from low latitudes to high, exactly the same effects are observed as going from day to night.

The President calculates that the value of the earth's field at Huancayo, as measured by the quantity $f^x_{F_2}$-$f^o_{F_2}$ is 0.30 gauss compared with 0.45 gauss in England, both values agreeing closely with the values found 10 years ago.

M^r^. Millington gives a short abstract of a theoretical paper showing charts of ionization density for different latitudes at different seasons of the year, based on Chapman's theory of ionization by monochromatic radiation. The maximum ionization in E region occurs approximately at noon, but for the F_2 region it is about 1 3/4 hours after noon, this interval increasing

with latitude. Further curves show that there is no ionization at the Pole at midwinter. There is no sign in the charts of the noon dip and 1800 maximum observed in F_2 owing to the simplifying assumptions made in applying the theory.

M. Bureau résume le rapport qu'il a établi avec MM. Habert et Failletaz au sujet de l'observation des atmosphériques pendant l'Année Polaire. Des stations d'enregistrement non directif ont fonctionné à Paris, Tunis, Rabat, Tamanrasset (Sahara), Scoresby-Sund (Groënland), Zi-Ka-Wei (Chine), et M. Lugeon en a de son côté fait fonctionner à Varsovie, Tromsoë et l'île des Ours. Enfin un enregistrement directif (goniomètre à secteur étroit) a fonctionné à Paris. La plupart des enregistrements ont été assurés sur 27 kc/s (11000 mètres). Les résultats mettent en évidence l'existence d'un nombre relativement restreint de grands foyers mondiaux d'origine en général continentale. A Paris, on relève ainsi au début de la nuit des sources orientées au Sud (foyer africain), puis dans la deuxième partie de la nuit, des sources orientées entre le NW et le SW suivant la saison (foyers américains) tandis que sur tout le secteur oriental des foyers se manifestent pendant les après-midi d'été.

— La variation diurne des atmosphériques dans les régions polaires confirme ces résultats; elle montre de plus l'existence d'un maximum principal de jour en été que les enregistrements de M. Lugeon ont particulièrement mis en évidence. L'explication de ce maximum et la localisation des sources qui le produisent présentent un grand intérêt au sujet du mode de formation de certaines sources d'atmosphériques; des turbulences et des mouvements de convection de l'atmosphère (instabilités de la nature des fronts froids) dans les régions polaires pourraient, en effet, les provoquer sans être accompagnés d'orages.

Le *Lt. Habert* rend compte des observations faites à Scoresby-Sund sur l'intensité des signaux de différentes stations commerciales et montre que cette intensité est inversement proportionnelle à l'activité magnétique.

Le *Dr. Lugeon* rend rapidement compte des observations qu'il a faites sur les atmosphériques pendant l'Année Polaire et suggère l'idée que la différence de température entre la mer et la terre pourrait être une source fréquente d'atmosphériques.

Dr. la Cour, President of the International Polar Year Committee, is invited to bring the session to a close by relating some of the magnetic work during the Polar Year. Before the Polar Year there were in the arctic America (Greenland included), in the European arctic sector (North of 64° N) and in Africa, 3, 5 and 1 observatories respectively making magnetic registerings. During the Polar Year these figures were increased to 11, 15 and 6 respectively. About 200 km. of curves had been obtained by the special Polar Year quick new recorders only. The object of the work was to obtain data on the world-wide magnetic disturbances, and curves were shown which illustrated the development at various stations of the sudden commencement of a magnetic storm. Small oscillations, some of quite a local character and others occuring simultaneously at stations far apart were next illustrated. Another type of oscillation of an intermittent character was shown. Some of these oscillations were found to be connected with earthquakes.

Dr. la Cour emphasises the necessity for a definition of magnetic activity suitable for the study of the intersections of magnetic disturbances and radio-electricity, and concludes his remarks by requesting all investigators to send copies of their published observations made during the Polar Year to the bureau of the International Polar Year Commission at Copenhagen, where a complete collection of the magnetic records would also be available to investigators.

La séance est levée.

Sous-Commission 1. — Mesures de l'Ionosphère

Sub-Commission 1. — Ionospheric Measurements

Séance du mercredi 12 septembre. — Meeting held on Wednesday, September 12th.

1. La séance est ouverte à 14.30 heures, sous la présidence du Prof. E. V. APPLETON, Président de la Sous-Commission, assisté de M. A. F. Wilkins comme Rapporteur.

2. Assistent à la séance : MM. T. L. Eckersley, le Prof. Dr. Jhr. G. J. Elias, le Lieut. de Vaisseau J. Habert, le Prof. F. E. W. Hackett, le Dr. Hafstad, R. A. Heising, R. Naismith, S. Namba, l'Ing. Picault et le Dr. White.

3. Le premier sujet discuté se rapporte à la *Nomenclature.*

The President suggests that some agreement is desirable as to the acceptability of the term « Ionosphere » which is already in fairly common use.

M^r. Eckersley thinks the term suitable on account of his brevity, while

M^r. Heising states that it is in general use in the U. S. A., and that he has heard no objection to its use in that country.

Dr. Hafstad also supports the use of the term.

M^r. Naismith while agreeing with the suitability of the term states that some limits of height are desirable.

Dr. White thinks that some definition of the meaning of « Ionosphere » is required.

After some discussion the following definitions are formulated :

(*a*) The ionosphere is the sphere of air whose predominating physical characteristics is ionization (President).

(*b*) The ionosphere is that part of the upper atmosphere which is ionized sufficiently to affect the propagation of wireless waves (M^r. Heising).

On propose à la Sous-Commission de mettre au vote la motion d'adopter le terme « Ionosphère » avec les deux définitions ci-dessus; cette proposition est admise.

4. La Sous-Commission s'occupe ensuite de l'*emploi des termes « layer » ou « couche »* à appliquer aux parties de l'ionosphère;

The President states that, in his opinion, the term « region » is more suitable having regard to the experimental evidence.

This opinion is also sheared by Messrs *Heising, Hafstad, Eckersley* and *Namba.*

Après une courte discussion au cours de laquelle, il est signalé que les termes « Schicht » et «Couche » sont d'usage courant en Allemagne et en France, on convient que le terme « région » est plus approprié et il est décidé de l'utiliser à l'avenir.

5. *The President* states that two fundamental methods have been used for ionospheric measurements, namely :

(*a*) the frequency-change method,
(*b*) the pulse method.

At the present time it is being found that all measurements hitherto made with the first of these methods can be done equally well and sometimes better with the pulse method, and that, as a result, it would be necessary henceforward to talk in terms of this method. Arising out of this it becomes necessary to decide on some name for the time taken by pulse signals in their travel up and down from the ionosphere. This the Chairman has called the « group time ».

Dr. Hafstad also uses this term in preference to « reflection » time.

M^r. Eckersley prefers « group delay ».

La Sous-Commission décide d'adopter l'expression « group delay ».

6. *The President* then points out that in America the term « virtual height » is applied to a quantity which is called « equivalent height » in England.

M^r. Heising thinks the term « equivalent height » is less suitable than the term « effective height ».

La Sous-Commission n'est pas favorable à l'emploi de l'expression « hauteur effective » en raison de l'usage qu'on peut en faire relativement à l'antenne. Finalement elle adopte les expressions «hauteur équivalente » ou « equivalent height » et « hauteur virtuelle » ou « virtual height », et elle recommande, lorsqu'il sera fait usage de l'une de ces dénominations dans un écrit, d'insérer une note spécifiant que ces deux expressions ont la même signification.

7. Il est décidé de faire usage des symboles suivants :
P pour le trajet optique,
P' pour le trajet équivalent ou virtuel,
f pour la fréquence.

8. *The President* states that the two commonest ionospheric measurements are those of :
(*a*) Virtual path as a function of time (P-t).
(*b*) Virtual path as a function of frequency (P'-f).

In arranging an international programme of ionospheric measurements, it would be necessary, in the case of class (*a*) measurements, to decide on the recording frequency. During the Polar Year, 2 and 4 Mc/s. have been used for this work.

Prof. Elias suggests 2, 3 and 4 Mc/s. for futur work.

La séance est levée à 15.45 heures.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

La séance est ouverte à 9.45 heures, sous la présidence du Prof. E. V. APPLETON, assisté de M. A. F. Wilkins comme rapporteur.

2. Assistent à la séance : MM. L. H. Bainbridge-Bell, le Prof. S. Chapman, le Dr. J. H. Dellinger, le Prof. Dr. Jhr. G. J. Elias, le Dr. Hafstad, R. A. Heising, A. Jensen, le Prof. R. Jouaust, I. Koga, le Dr. J. Lugeon, le Commandant C. Matteini, le Prof. H. R. Mimno, R. Naismith, S. Namba, J. A. Ratcliffe, E. H. Shaugnessy et F. W. G. White.

3. *The President* asks if anyone of the members has comments to bring forward concerning the resolutions taken at the first meeting.

M^r. Ratcliffe raises a point in connection with the definition of the terme « Ionosphere ». He suggests the introduction of the word « relatively » into the definition of the ionosphere given in definition (*a*) at the previous meeting (¹). This would then read :

« The ionosphere is the sphere of air whose relatively predominating physical characteristic is ionization ».

He thinks that definition (*b*) is better.

On engage ensuite une discussion en vue de préciser si par « Ionosphère », on désignerait l'atmosphère tout entière ou seulement l'enveloppe d'air mal définie dans la haute atmosphère.

Finalement, on décide de ne retenir que la dernière acception et on adopte la définition suivante :

« L'Ionosphère est la partie de la haute atmo-

(¹) See p. 46.

sphère suffisamment ionisée pour affecter la propagation des ondes radioélectriques ».

4. *The President* reports that Messrs Hafstad and Naismith have prepared a programme of measurements suitable for international execution.

These suggestions are presented by *M^r. Naismith* and summarized in a table (¹).

Les renseignements demandés peuvent être groupés comme suit :

(*a*) Variation de l'ionisation avec la latitude.

(*b*) Variation de la hauteur virtuelle avec la latitude.

(*c*) Variations anormales.

Ces renseignements peuvent être fournis par des mesures des types ci-dessous :

a) *Mesures « P -t »* (fréquence fixée). — On recommande une fréquence de 3 Mc/s. : à cette fréquence, des échos de E ou de F peuvent pratiquement être obtenus pendant toute l'année.

On recommande de discriminer la polarisation, si possible.

On suggère les périodes suivantes pour les observations :

Première priorité : Journées de 1er et 2^e ordres (²).

Recommandation générale : Mesures continues.

Prof. Elias states that, in Holland, it is found impossible, owing to Post Office regulations, to work continuously on 3 Mc/s. but that he has been working on 4 Mc/s., and thinks that 2 Mc/s. or 4 Mc/s. will be better in his case.

The President therefore suggests that if 3 Mc/s. is prohibited in any country for ionospheric work, recording should be done on 2 Mc/s. and/or 4 Mc/s.

La première partie du programme résumé au tableau est adoptée (³).

b) *Mesures de « P-'f »*. — On décide d'effectuer ces mesures au midi local, tous les Jours Internationaux, et on recommande, d'une façon générale, de faire, si possible, ces mesures chaque jour. Chaque mesure devrait couvrir toute la gamme de fréquences pour lesquelles on peut observer des échos.

c) *Mesures de « P'-f » pour des périodes de 24 heures.* — On décide d'entreprendre ce travail quatre fois par an et, d'une façon générale, on recommande d'effectuer ces mesures les jours de 3^e et 4^e ordres. On fera une mesure de *P'-f* toutes les heures.

d) *Mesures automatiques de « P'-f »*. — Ces mesures seront du type de celles effectuées actuellement à Washington D. C., Huancayo (Pérou), Whateroo (Australie) et à Slough.

Prof. Dr. Elias states that he will be able to collaborated in this type of test but only at special times and not during the evening.

Le *Dr. Lugeon* a les appareils nécessaires pour prendre des mesures presque continues en Pologne. Il ne devrait les interrompre qu'une fois par mois.

The President says that the frequency range employed in this work has been limited to the range of one coil at the transmitter and has been 2.5 Mc/s. to about 5 Mc/s. at both Slough and Washington. The ideal would be 1-8 Mc/s.

Dr. Hafstad points out that the increase of frequency range to cover 1-10 Mc/s. has been made at Washington.

M. Bainbridge-Bell calls attention to a recent letter in « Nature » from Gilliland, describing briefly this new Washington apparatus (¹), and gives the following extract :

« Work is in progress on the replacement of the preliminary equipment by permanent equipment which will record over a frequency range

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(¹) See p. 50.

(²) Voir p. 112, la définition des Journées Internationales.

(³) Voir p. 50.

(¹) *Nature*, vol. 134, p. 379, Sept. 8, 1934.

from 500 to about 12.000 kc/s. The apparatus is arranged to cover this range in four bands. In order to maintain the receiving set accurately in tune with the transmitter, the latter is provided with two oscillators, one variable and the other fixed. The fixed oscillator is set in a value equal to the intermediate frequency of the superheterodyne receiving set. The output from the antenna is either the sum or the difference frequency depending on which band is being used. The variable oscillator of the transmitter serves also as the oscillator for the receiving set. Thus only the detector of the receiving set is required to be tuned, and this tuning is not critical ».

Après discussion, la Sous-Commission décide de recommander la réalisation d'enregistrements automatiques de P'-f, mais elle ne spécifie pas de gammes de fréquences, celles-ci devant être déterminées d'après des considérations dépendant de la latitude.

5. *The President* proposes then to examine a few questions of nomenclature, particularly the names to be given to the various parts of the ionosphere, and the letters to be used to distinguish these parts.

Prof. Elias says that his experiments have clearly demonstrated that there are two distinct layers, one being only observed during the day, which is produced by the action of the ultraviolet solar rays and whose height varies between 200 and 250 kilometres, while the other is only observed at night and its height varies between 300 and 450 kilometres. There is a very remarkable difference between the echoes emitted by those layers, the echo signals received by the cathodic oscillograph being during the night of an appreciable width, while during the day they are narrow. Which shows that the reflecting layer is narrow during the day and relatively broad during the night. At last, his experiments have never shown the least correlation between the appearance of the nightly layer and the behaviour of the dayly layer. He is of the opinion, that it is not desirable to use the same notation for the higher reflecting layer by day as well as by night.

The Chairman asks if any other worker has arrived at similar conclusions from his work. He observes that Prof. Elias has only used two frequencies : 2 and 4 megacycles. He thinks that using a frequency range, one is able to observe that the height of the layer varies continuously with frequency.

Prof. Chapman thinks that since the nature of the phenomena does not yet seem very well understood, it would be premature to actually change the nomenclature.

M^r^. Ratcliffe explains that in his own experiments he has arrived at some wrong conclusions by using a few isolated frequencies but has immediately modified the conclusions when he has used a continuous range of frequencies. He thinks that Prof. Elias' conclusions are due to the fact that he used only a few isolated frequencies.

Les désignations E et F pour les deux régions, de nuit aussi bien que de jour, sont acceptées à la majorité des voix.

La discussion continue ensuite sur la façon de désigner les fréquences critiques, et sur l'emploi des mots « *ordinaire* » et « *extraordinaire* » appliqués aux deux rayons.

The President exposes the nomenclature recently adopted by the National Bureau of Standards, and asks if the members think it necessary to modify this nomenclature.

Prof. Elias prefers the names « *gauche* » et « *droit* » — « *left-handed* » and « *right-handed* » instead of « *ordinary* » and « *extra-ordinary* ».

The President observes that the ordinary ray sometimes has a right-handed polarization.

Prof. Chapman says that if Prof. Elias' suggestion is adopted, the names would have to be changed in the Southern hemisphere.

M. Ratcliffe finds the words « *ordinary* » and « *extra-ordinary* » very suitable although they are taken in significance slightly different from those used in optics. The terrestrial magnetic field only influences on the extra-ordinary ray.

Mise au vote, la proposition de conserver les termes « *ordinaire* » et « *extraordinaire* » est adoptée, le Prof. Elias votant contre.

M. Ratcliffe proposes for the designation of the critical, frequencies of those two rays, « $f^o_{E_1}$ » and « $f^x_{E_1}$ » instead of « f'_{E_1} » and « f'_{E_1} ».

Après discussion, cette proposition est adoptée. Les fréquences critiques seront par conséquent, désignées par :

$$f_{E_1}, f_{E_2}, f_{F_1}, f_{F_2}, \text{ etc.,}$$

et, lorsque l'on désire distinguer entre les rayons ordinaire et extraordinaire, par :

$$f^o_{E_1}, f^x_{E_2}, \text{ etc.}$$

6. *Mr. Naismith* refers to Ursigrams and general interchange of data.

The President says that he is of the opinion that it is not necessary to broadcast Ursigrams and that a weekly Ursigram is sufficient for most purposes. The interchange of data is liable to lead to difficulties and suggests that a committee should be appointed to report progress to the Secretary General for the next Congress.

Dr. Hafstad suggests that this committee might be used for the interchange of data on abnormalities.

Mr. Heising suggests that the same committee might transmit available data from commercial circuit operation for comparison with ionospheric data.

The President thinks that separate groups should use the commercial transmission data and correlate with their own ionospheric data.

La Sous-Commission propose de constituer un Comité ayant pour mission :

a) De tenir la liste des pays effectuant des mesures de l'ionosphère ;
b) D'élaborer un programme de Journées Nationales ;
c) D'aider à l'échange de renseignements ;
d) D'annoncer les observations spéciales sur les éclipses, les phénomènes météoriques, les troubles magnétiques, etc ;
e) De recueillir les données fournies par les trafics commerciaux et pouvant être comparées aux résultats des mesures de l'ionosphère.

7. *The President* then proposes the sub-commission of Polar-Year to be dissolved, and its works to be continued by a Permanent Committee which would deal with the matters 6 (*a*) to 6(*e*) above.

La Sous-Commission décide à l'unanimité de dissoudre la Sous-Commission de l'Année Polaire et de confier ses recherches au Comité Permanent dont question au 6 ci-dessus.

8. On passe ensuite à l'établissement des résolutions à présenter à la séance plénière de la Commission II (¹).

La séance est levée à 11.30 heures.

Programme des mesures

Genre de mesure	Date des mesures	
	Minimum nécessaire	Recommandations générales
1) *P'* — *t*, sur 3 mégac. si possible, avec polarisation.	Jours internationaux de premier et de second ordres.	Mesures continues.
2) *P'* — *f*.	Au midi local, chaque jour international.	Au midi local, tous les jours.
3) *P'* — *f*, pendant au moins 24 heures.	Aux solstices et aux équinoxes.	Jours internationaux de troisième et quatrième ordres.

(¹) Voir p. 110.

Sous-Commission 2. — Des Taches solaires

Sub-Commission 2. — Sunspots

Séance du vendredi 14 septembre. — Meeting held on Friday, September 14th.

La séance est ouverte à 16.30 heures sous la présidence de M. R. A. Heising, Président de la Sous-Commission, assisté de M. L. H. Bainbridge-Bell, comme rapporteur.

Assistent à la séance: MM. le Commandant R. Bureau, le Prof. S. Chapman, D. L. Eckersley, L. Espenchied, le Lt. de Vaisseau J. Habert, S. Namba et le Prof. H. Yagi.

The President states that the main business is *to discuss a proposition* of Shelleng (originated by Dr. G. E. Hale) *for measures to increase knowledge of correlation of Radio and Sunspot phenomena.* Schelleng states that effect of Sunspot on Radio is only partially known. Skellet has tried to correlate Radio conditions with spectro-heliograph observations. Schelleng believes that it is desirable to make continuous observations on the sun throughout 24 hours of the day by spectro-heliograph or otherwise, to detect causes of disturbance in radio transmission that are not at present attribuable to sunspot phenomena. He suggests a program of a week's observation to begin 27 days after a magnetic storm.

Prof. Chapman mentions the Committee of the International Council of Scientific Unions (with members representing the U. R. S. I. and the Astronomical and Geophysical Unions) for Solar and Terrestrial Relationships.

Bell Laboratories have recorded Radio Character in 27 day periods.

Le *Lt. de Vaisseau Habert* déclare que la période de 27 jours affectant la propagation des ondes radio-électriques est plus remarquable dans la zone de fréquence maximum des aurores polaires; il préconise, en conséquence, l'installation de stations d'observation en Islande et en Norvège.

M. Eckersley confirms the above suggestion and says magnetically disturbed days show violent variation of transmission constants, and that correlation Radio-Magnetic is more marked than Radio-Sunspot or Magnetic-Sunspot.

Le *Commandant Bureau* signale qu'il serait très utile de disposer, dans les recherches sur les parasites atmosphériques, d'une documentation relative aux caractères radioélectriques et magnétiques de chaque jour.

En effet, les parasites atmosphériques que nous recevons sont la conséquence de l'action de la propagation sur les ondes naturelles rayonnées par les foyers d'atmosphériques.

L'un des problèmes posés par toute recherche sur les atmosphériques consiste donc à séparer l'action due aux foyers mêmes et celle due à la propagation.

Les résolutions suivantes sont établies pour être soumises à la Commission II :

La Sous-Commission exprime le désir de voir continuer l'étude des relations entre les phénomènes solaires et géophysiques, et la radiopropagation.

La Sous-Commission estime que ce travail pourrait être poussé plus avant si les compagnies et organisations publiaient les renseignements qu'elles obtiennent sur les caractères de la propagation des circuits, de façon à permettre leur emploi par les Astronomes, Géophysiciens et autres chercheurs, pour en établir les relations avec les observations que ceux-ci pourraient faire.

La Sous-Commission recommande de plus, que pour le moment, le caractère de la propagation ne soit pas exprimé en plus de cinq degrés et que les renseignements soient publiés sous forme de diagrammes comprenant des périodes de 27 jours.

Enfin, la Sous-Commission souhaite que le Comité Exécutif examine la possibilité de centraliser les réponses, 1°, en prenant des mesures pour que les renseignements soient réunis et publiés, et 2°, en étudiant le meilleur mode de présentation de ces renseignements.

La séance est levée.

Sous-Commission 3. — Action réciproque des ondes radio-électriques

Sub-Commission 3. — Interaction of radio-waves

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

1. La séance est ouverte à 9.45 heures, sous la présidence du Dr. B. VAN DER POL, Président de la Sous-Commission, assisté du Dr. Mary Taylor, comme rapporteur.

2. Assistent à la séance : MM. P. Baudoux, T. L. Eckersley, L. Espenchied, le Prof. Hackett, H. L. Kirke, le Prof. C. Manneback, le Prof. R. Mesny, l'Ing. Picault, W. P. Wilson et le Prof. H. Yagi.

3. *The Chairman* gives an account of the paper by himself and M. van der Mark (¹).

4. *Discussion du document n° 62* (¹). — *Mr. Eckersley* remarks that experiments by himself and Mr. Tremellen at Chemsford have led to the same conclusions as those described by the President, but the path from the wanted station to the receiver seems to pass within about 500 km. of the interfering station (Luxemburg) instead of only 250-300 km. as found by the President. M. Eckersley has also observed that the low frequencies are more strongly modulated. The stations on which interference has been, are all within an arc with Luxemburg as the interfering station. In experiments with M. Smith, he has tried to observe the difference of tones from Leipzig of frequency ω_2-ω_1 in the 900 metre band; something was heard but was not identifiable. He asks the President to define more precisely the meaning of the terms « first » and « second » order effect.

The President explains that the term « second » order effect arises by considering the ordinary linear effect to be of zero order; the modulation effect only arises from the next-but-one term of the third degree, in the non-linear expansion so it migth be termed a « second » order effect. Terms of frequency $(2\omega_2\text{-}\omega_1)$ and $(2\omega_1\text{-}\omega_2)$ would, however, also be expected to arise.

Mr. Eckersley remarks that, in general, effects due to thermal agitation are large, compared with effects due to the velocity of production of electrons.

The President says that the change of the number of impacts per seconds due to the interfering station would only give a very slight rise in temperature.

Mr. Eckersley thinks the Doppler effect would be small. He suggests investigating the directional effect of the interference.

M. l'Ing. Picault attire l'attention sur les effets d'interférence observés pour les stations de Bordeaux et dit qu'il espère que l'étude d'effets semblables sera étendue aux fréquences autres que celles réservées à la radio-diffusion.

Mr. Kirke and *Mr. Wilson* describe a case of possible interference in connection with Daventry stations.

After further discussion, in which *Mr. Espenchied* and *Mr. Kirke* also take part, *the President* suggests that definite experiments may profi-

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(¹) Document n° 62, p. 192.

tably be made on the subject; Luxemburg station may be asked to emit a programme of Morse dashes on a low frequency during broadcasting hours and listeners all over Europe may be asked to report on which stations they hear interference from Luxemburg.

5. On nomme ensuite un sous-comité constitué par MM. Eckersley, Kirke et Picault, pour étudier et organiser des expériences internationales de base; les rapports reçus seront envoyés au Dr. van der Pol aux fins d'analyse et de présentation des résultats (1).

M. Espenchied drews attention to the possibility of mistaking effects due to the receiver for the true interference effect and suggests sending out engineers with proper measuring apparatus as observers.

M. Wilson suggests taking measurements on the « first » order sum and difference of frequencies. The presence of such effects would prove that the phenomena is due to non-linearity.

6. La séance est levée à 11.15 heures.

Rapport du Sous-Comité de l'Action Réciproque des Ondes Modulées, dans l'Ionosphère

Report of Sub-Committee on Interaction of Modulated Radio-Waves in the Ionosphere

1. Le Sous-Comité estime que l'importance de la question est suffisante pour justifier l'organisation de recherches étendues.

2. Il est proposé de demander à certains postes européens d'émission à ondes longues, de collaborer aux recherches, en prêtant leurs émetteurs pendant deux heures de nuit, une fois par semaine, et ce pendant trois semaines. La modulation serait intermittente d'environ 80% à 200 p. p. s., l'intermittence étant de l'ordre de 2 secondes.

3. Le Dr. van der Pol est prié de s'enquérir si le poste de Luxembourg serait disposé à collaborer comme stipulé en 2.

4. M. Picault ou l'U. R. S. I. est prié de s'enquérir si Radio-Paris serait disposé à collaborer comme indiqué au 2.

5. On demande aux délégués de tous les pays d'organiser un système de réception et d'écoute en vue des essais et de veiller autant que possible que les récepteurs utilisés ne soient pas de nature à causer l'un des effets étudiés et que seuls des observateurs expérimentés soient utilisés.

1. The Committee is of the opinion that the matter is of sufficient importance to warrant a wide research being undertaken.

2. It is proposed that certain European long-wave stations be asked if they would co-operate to the extent of lending their transmitters for the period of two hours on one night in each week, for three weeks. The modulation to take the form of an intermittent modulation of about 80% at 200 p. p. s., the intermittency to be of the order 2 seconds.

3. Dr. van der Pol is asked to inquire from Luxemburg whether that station is prepared to co-operate as in 2.

4. M. Picault or U. R. S. I. is asked to enquire if Radio Paris would be prepared to co-operate as in 2.

5. Representatives of each country are asked to organise listeners and receivers for the tests and to endeavour as far as possible to ensure that the receivers used are not likely to cause any of the effects being looked for, and that as far as possible experienced observers only are employed.

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(1) Voir ci-après le rapport de ce sous-comité.

6. *a*) On demande qu'un délégué de chaque pays réunisse et analyse autant que possible, les rapports de son pays, et les envoie au Dr. van der Pol.

b) La Pologne est priée de faire des expériences indépendantes en utilisant Varsovie comme station interférente.

c) L'U. R. S. S. est sollicitée pour exécuter une série d'essais semblables sur son territoire.

7. La British Broadcasting Corporation est disposée à effectuer une série séparée d'essais en utilisant ses propres stations, tout en collaborant aux expériences européennes.

8. *a*) *Nature des essais.*

Les essais doivent être exécutés pendant les périodes d'obscurité.

b) Chaque observateur devrait accorder son récepteur successivement sur chacune des stations européennes qu'il reçoit clairement et écouter l'interférence du son de modulation de la station d'interférence.

c) Au début on estimait qu'une période d'une heure par nuit était suffisante, mais des considérations ultérieures ont montré qu'il peut ne pas être possible pendant ce temps de faire assez d'observations suffisamment longues pour être de quelque valeur ; c'est pourquoi, on a proposé des périodes de deux heures.

d) Le but des essais est de déterminer le plus loin possible, les zones couvertes par l'interférence ; pour cette raison, des observations devraient être faites sur toutes les stations reçues clairement, même si l'on n'a pas la certitude que le phénomène d'interférence se produira ou non.

e) Il serait désirable que le document n° 62 soit mis en circulation.

6. (*a*) A representative of each country is asked to collect and analyse as far as possible the reports of his country and send them to Dr. van der Pol.

(*b*) Poland is asked to carry out separate tests using Warsaw as the interfering station.

(*c*) That U. R. S. S. be asked to carry out a series of similar tests in their own country.

7. The British Broadcasting Corporation is prepared to make a separate series of tests using their own stations, as well as co-operating in the European tests.

8. (*a*) *Nature of tests.*

The tests must be carried out in the dark period.

(*b*) Each observer should tune his receiver to each of the strongly received European stations in turn and listen for interference from the modulating tone of the interfering station.

(*c*) It was originally thought that a period of one hour on each night would be sufficient, but further consideration shows that it might not be possible in the time to make sufficient and sufficiently long observations to be of value, and therefore a period of two hours is proposed.

(*d*) The object of the tests is to determine as far as possible the area covered by the interference ; and for this reason observations should be made on all strongly received stations irrespective of whether or not it is considered that the interference phenomenon is likely to be present.

(*e*) A copy of Paper n° 62 should be circulated.

Sous-Commission 4. — Les Éclipses

Sub-Commission 4. — On Eclipses

Séance du vendredi 14 septembre. — Meeting held on Friday, September 14th.

La séance est ouverte sous la présidence du Prof. S. Chapman, Président de la Sous-Commission, assisté de M. R. H. Barfield comme rapporteur.

Assistent à la séance: MM. le Dr. Hafstad, le Prof. R. Jouaust, le Dr. F. W. G. White et le Prof. H. Yagi.

The President calls attention to three papers, nº 35, 36, and 56, which are to be discussed.

He proceeds to outline briefly the contents of nº 56 (¹) on « Ionization Changes during Solar Eclipses », by Prof. E. V. Appleton and himself. The results of the various observing groups confirm that ionization in the E and F_1 layers is caused by the agency of ultra-violet light or other quick travelling rays. The evidence for corpuscular ionization is in all cases either negative or ambiguous.

On passe ensuite à la discussion de cette étude.

Prof. Yagi then comments briefly on Paper 35 (²), stating that the results plainly established the occurence of night conditions during the éclipse of February 14 th, 1934, but did not seem to distinguish clearly between the various layers (E, F_1, etc.).

Dr. Hafstad then summarises a paper by L. V. Berkner suggesting that arrangements should be made to observe the eclipse of 1937, and suggests a convient side for the purpose.

The President suggests that it would be advisable to recommend the preparation in advance, of charts of optical and corpuscular paths for future eclipses.

Cette proposition rencontre l'approbation de la Sous-Commission.

La Sous-Commission convient, en suite aux conclusions du document nº 56 (¹), de recommander la concentration des recherches dans la région F_2 et dans les regions intermédiaires; des renseignements amplement suffisants pour le moment, existent pour la région E.

Dr. White states that he believes a permanent Committee is to be formed for ionospheric observations, which might be a suitable body to perform the above functions.

On discute ensuite les méthodes de mesure à employer pour les travaux futurs. On décide d'utiliser les méthodes donnant le plus rapidement possible, les mesures des quantités intéressées.

Le *Prof. Jouaust* propose la formation d'une Commission permanente analogue à celles constituées par les institutions astronomiques; cette Commission aurait pour mission la préparation, quelque temps avant l'éclipse, d'un programme défini, de même que l'entrée en pourparlers avec les Gouvernements pour l'obtention des des crédits nécessaires.

Dr. White suggests that the proposed Permanent Committee on ionospheric observations, already referred to, might also be asked to undertake these tasks.

La Sous-Commission décide de confier à la même Commission Permanente l'étude des observations de l'ionosphère et la préparation des observations à faire lors des éclipses.

Dr. Hafstad suggests that the special committee should make some attempt to standardise the form in which results are submitted.

La proposition du Dr. Hafstad est acceptée.

La séance est levée.

(¹) See p. 189. (²) See p. 147.

(¹) Voir p. 189.

Sous-Commission commune aux Commissions II et V. — Etude de la Propagation d'Ionisation

Joint Sub-Commission to Commissions II and V. — Ionization Propagation Analysis

Séance du vendredi 14 septembre. — Meeting held on Friday, September 14th.

La séance est ouverte à 15.30 heures, sous la présidence de M. T. L. Eckersley, Président de la sous-commission, assisté du Dr. Mary Taylor comme rapporteur.

Assistent à la séance : MM. P. Baudoux, L. A. Briggs, Prof. Dr. Jhr. Elias, Prof. Hackett, Prof. C. Manneback, S. Namba, J. A. Ratcliffe, Dr. B. van der Pol.

The President opens the meeting by remarking on the importance of both practical results and theoretical work on the analysis of radio wave propagation.

The President calls on Prof. Elias to give an account of his paper, Document No 3 (1).

Prof. Elias states that he has suggested, in a paper written in 1926, that there are two ionization regions in the upper atmosphere, one due to solar ultra-violet radiations, and one due to corpuscles deflected by the earth's magnetic field. He has calculated the ionic density and found that the logarithmic gradient of ionization should be much steeper for corpuscular than for solar ultra-violet radiation. The graph of ionization N due to the latter alone has roughly the form (fig. 1) and its logarithm (fig. 2) is roughly represented by $\log \frac{N}{N_0} = e^{ah}$, where a includes the effect of temperature. In calculating the reflection coefficient, an approximation is found by taking the tangent at the approximate reflection point $N_1 : g = g_0 e^{kz}$ and the dielectric constant $\varepsilon = 1 - \eta e^{kz}$ where $\eta = \frac{\omega l}{v_0}$, l free molecular path, v_0 thermal velocity of electrons, η measures the damping. The reflection coefficient is approximately $e^{-p \beta \cos \Phi}$, where $p = \frac{2\omega}{ck}$, $\tan \beta = \frac{1}{\eta}$ Φ angle between ray and vertical.

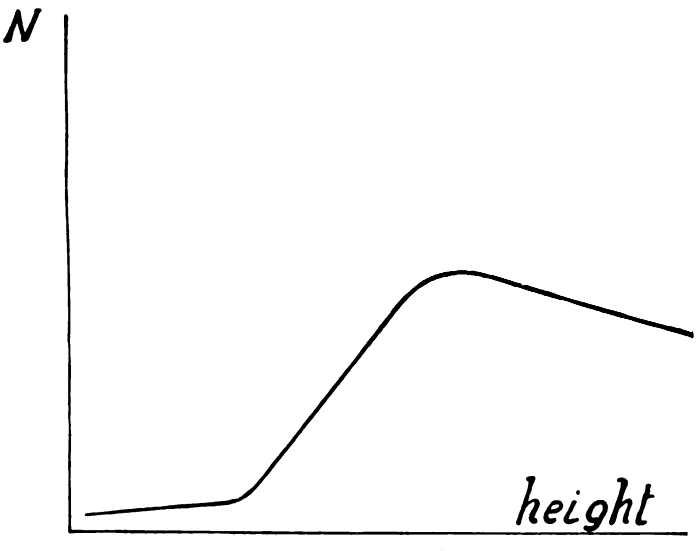

FIG 1

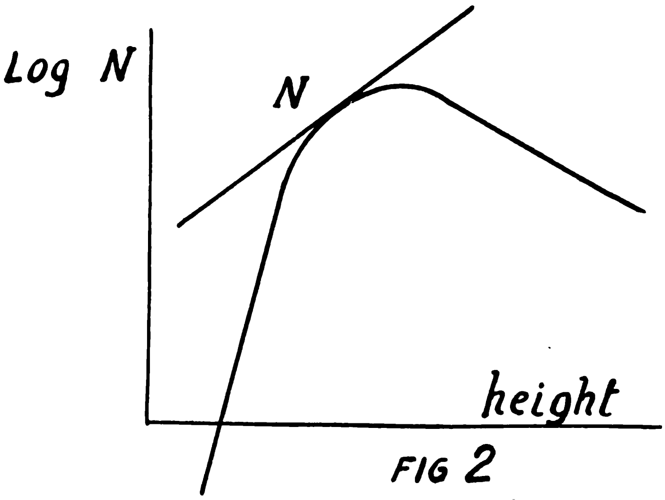

FIG 2

He has checked this experimmentally from fading curves of Rotterdam-Delft transmissions (base line about 11 km.). Prof. Elias states that he has just succeeded in approximating further along the curve. There is, however, a whole *region* of reflection ; the values given for the height are only approximate.

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(1) See p. 121.

The density n_1 of ions necessary for reflection is given by

$$n_1 = \frac{m\,\omega^2 \cos^2 \Phi}{4\,\pi\,q^2}\,\frac{\sqrt{1+\eta^2}}{\eta}$$

(q charge, m mass of electron).

For $\omega l \gg v_0$, we get the usual formula $n_1 = \frac{n\,\omega^2 \cos^2 \Phi}{4\,\pi\,q^2}$. The F-region is given by $\eta \gg 1$.

In the E-region, however, Prof. Elias considers η to be small; there the conductivity is probably large compared to the thermal effect. η also depends on frequency and is small for long waves.

The President remarks that Prof. Elias has touched upon the limitations of the ray theory, which is only adequate for $\omega l \gg v_0$. His own (M. Eckersley's) work gives the proper values and possible rays for a medium with parabolic distribution of ionization. The ray theory does hold for high collision frequencies.

Dr. van der Pol refers to Epstein's papers (¹). The question is when does Fermat's principle hold ?

Mr. Ratcliffe draws attention to the fact that Prof. Appleton has shown that E-region acts as a dielectric reflector, for a frequency of 4 mc/s. Prof. Appleton has deduced this from magneto-ionic theory.

Prof. Elias says that, to include the effect of a magnetic field, a 6th order differential equation is required. This can only be solved in simple case.

The President states that he is well on the way to solving the equations for a parabolic distribution ionization by his phase-integral method.

Dr. van der Pol remarks that the Kramers-Brillouin-Wentzel method would give the ray solution of the differential equation and would probably determine all cases in which Prof. Elias' method could be applied.

The President points out that the limitations of the ray theory are determined by :

(1) the collision frequency,

(2) steep gradients in the ionosphere.

Prof. Elias remarks that a large dielectric constant gives total reflection. There is difficulty in the discussion of behaviour near the singular points where $\varepsilon \to 0$. Reflection of impulse would be dealt with by inserting the reflection coefficient in the Fourier integral for the pulse form, this gives the time before the arrival of echoes. If η is large, the time is less than the time deduced from the effective heigth in Elias' theory, the phase velocity is $>$ C. If η is small, retardation, not acceleration, takes place.

Le *Prof. Manneback* donne un résumé d'une étude déjà ancienne (¹). Les lois de l'ionisation pourraient être prouvées en résolvant les équations en coordonnées polaires, et en comparant le nombre d'échos au nombre de rayons possibles trouvés par la théorie. Il fait remarquer que nous mesurons la vitesse de *groupe* et non pas de *phase*.

Debye a remarqué que l'équation des ondes optiques :

$$\Delta \Psi = f\,(x,y,z)\,\Psi,$$

en prenant :

$$\Psi = A\,e^{i\,\Phi},$$

donne :

$$(\nabla\,\Phi)^2 = n^2 + \frac{\Delta\,A}{A}.$$

Si le terme $\frac{\Delta\,A}{A}$ est négligeable, les lois d'optique géométrique sont valables, ce qui exige que les dérivées de f (constante diélectrique) soient $\ll 1$.

La séance est levée à 17 heures.

(¹) *Proc. Nat. Acad. Sci.*, 1930.

(¹) Congrès National des Sciences, Bruxelles 1930· Comptes rendus, p. 167-171.

Séance du mardi 18 septembre. — Meeting held on Tuesday, September 18th.

La séance est ouverte à 9.45 heures, sous la présidence de M. T. L. Eckersley, assisté du Dr. Mary Taylor comme rapporteur.

Assistent à la séance : MM. Prof. Dr. Jhr. Elias, Prof. Fortescue, Dr. Ing. Gorio, Prof. Hackett, Prof. R. Jouaust, Prof. C. Manneback, Prof. R. Mesny, R. Naismith, S. Namba, Okamoto, Dr. B. van der Pol, Prof. Dr. Wagner, Wilson.

The President invites Prof. Manneback to continue the resume of his work left unfinished at the adjournement of the last meeting : *Discussion of Relations between Wave and Geometrical Optics.*

Le *Prof. Manneback* commence par donner l'équation de l'onde d'après la théorie de Fresnel ou de Maxwell, sous la forme

$$(1) \qquad \Delta \Psi = \frac{\varepsilon \mu}{c^2} \frac{\partial^2 \Psi}{\partial t^2} + 4 \pi \gamma \mu \,.\, \frac{\partial \Psi}{\partial t}$$

(notations usuelles).

D'après l'argument de Debye, il obtient l'approximation de l'optique géométrique en écrivant :

$$\Psi = \mathrm{R}\left(e^{2\pi i ct/\lambda} . \mathrm{A}\,(x,y,z) \,.\, e \, \frac{-2\pi i \,\mathrm{S}\,(x,y,z)}{\lambda}\right)$$

$$(2) \qquad = \mathrm{A} \cos \frac{2\pi}{\lambda}(ct - \mathrm{S})$$

A réel ; λ, longueur d'onde dans le vide ; R signifie partie réelle de ce qui suit.

Ce qui donne $\left(\mathrm{K} = \frac{2\pi}{\lambda}\right)$

$(3a)$ $(\nabla \mathrm{S})^2 = \varepsilon \mu + \frac{1}{\mathrm{K}^2} \frac{\Delta \mathrm{A}}{\mathrm{A}} +$ des termes additionnels intervenant dans le cas de composantes électriques mais non pas de composantes magnétiques.

$$(3b) \qquad \frac{2}{\mathrm{A}} (\nabla \mathrm{S} \,.\, \nabla \mathrm{A}) + \Delta \mathrm{S} = -4 \pi \gamma \mu c$$

dans lesquelles :

$$(\nabla \mathrm{S})^2 = \left(\frac{\partial \mathrm{S}}{\partial x}\right)^2 + \left(\frac{\partial \mathrm{S}}{\partial y}\right)^2 + \left(\frac{\partial \mathrm{S}}{\partial z}\right)^2$$

$$(\nabla \mathrm{S} . \nabla \mathrm{A}) = \frac{\partial \mathrm{S}}{\partial x} \frac{\partial \mathrm{A}}{\partial x} + \ldots$$

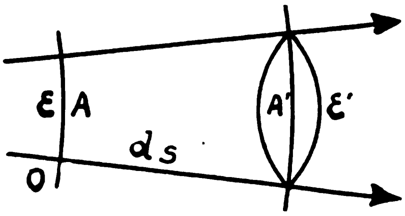
L'unité de longueur est ici de l'ordre de l'unité naturelle intervenant dans les problèmes pratiques à traiter par la méthode, c'est à dire de l'ordre de la longueur d'onde. Si $\frac{\Delta \mathrm{A}}{\mathrm{A}}$ est très petit quand A est mesuré pour une longueur d'onde, $\frac{\Delta \mathrm{A}}{\mathrm{A}}$ disparaît et l'équation devient :

$$(\nabla \mathrm{S})^2 = \varepsilon \mu,$$

expression du principe d'Huygens.

Près d'un dipole électromagnétique, en appliquant la théorie électrostatique, $\frac{\Delta \mathrm{A}}{\mathrm{A}}$ devient important lorsque le champ du dipole n'est pas sphérique, c'est-à-dire dans un rayon d'une longueur d'onde.

Pour intégrer 3 (*b*), on peut considérer un tube de rayons (voir fig.)



Ce qui donne $\Sigma \mathrm{A}_2$ = constante, comme l'équation régissant la propagation de l'énergie dans un tube de rayons (Σ, aire de la section droite).

En considérant l'amortissement, nous avons :

$$\Sigma . \mathrm{A}^2 = . \Sigma_0 . \mathrm{A}_0^2 e^{-4\pi c \mu \int_0^1 \frac{\gamma}{\sqrt{\varepsilon}} ds}$$

en décibels, l'*amortissement* est donc $\int_0^1 \frac{\gamma}{\sqrt{\varepsilon}}$ ds.

Pour que la méthode soit mathématiquement rigoureuse, l'équation $(\nabla \mathrm{S})^2 = \varepsilon \mu$ ne doit jamais avoir une solution singulière, c'est-à-dire ε doit rester positif, et également, $\frac{\Delta \mathrm{A}}{\mathrm{A}}$ doit rester petit.

Si l'on veut considerer les solutions singulières (y compris celles où $\varepsilon = 0$), on doit employer l'équation exacte avec les intégrales de phase; cette méthode plus générale est due à M. T. L. Eckersley.

Dr. van der Pol points out that Prof. Manneback has started from a linear equation and derived non-linear ones, with all their attendant difficulties. It is equivalent to the derivation of the Riccati 1st order equation from linear 2nd order equations.

The President remarks that the presence of the earth's magnetic field completely changes the character of the equations.

Le *Prof. Manneback* dit que l'on pourrait facilement étendre la théorie au cas où un champ magnétique intervient avec les composantes A_x, A_y, A_z. L'équation d'Hamilton devient

$$\left(\frac{\partial}{\partial x} - \frac{e}{c} A_x\right)^2 S + \left(\frac{\partial}{\partial y} - \frac{e}{c} A_y\right)^2 S + \\ + \left(\frac{\partial}{\partial z} - \frac{e}{c} A_z\right)^2 S + U = W$$

$$\text{ou } \Sigma \left\{ \left(\frac{S}{x}\right)^2 - 2 \frac{e}{c} \frac{S}{x} . A_x + S . \frac{e}{c} A_x^2 \right\} + U = W$$

Ce qui est l'équation d'optique géométrique dans un milieu non-isotrope.

The President then gives an account of his work on the theory of propagation in an ionized medium with an external magnetic field. A sixth order equation is obtained for any one component. He assumes for the components of Ψ the values

$$\Psi_1 = A_1 e^{-2\pi i S/\lambda}, \quad \Psi_2 = A_2 e^{-2\pi i S/\lambda},$$
$$\Psi_3 = A_3 e^{-2\pi i S/\lambda}$$

the neglected $\frac{\partial^2 S.}{\partial x^2}$.., in comparison with $\left(\frac{\partial S}{\partial x}\right)^2$; assuming that the ionization in the medium is a function of ε alone, the equation for the refractive index is found in the determinantal form

$$\begin{vmatrix} 1 - m^2 - \left(\frac{\partial S}{\partial z}\right)^2 & c_{21} & c_{31} \\ a_{12} & 1 - \left(\frac{\partial S}{\partial z}\right)^2 & a_{.2} + m \frac{\partial S}{\partial z} \\ a_{13} & m \frac{\partial S}{\partial z} + a_{23} & 1 - m^2 + a_{33} \end{vmatrix} = 0$$

where m is the direction cosine of the angle made by the ray in the y-direction. The a's are functions of H_x, H_y, H_z. This equation is biquadratic in $\frac{\partial S}{\partial x}$; it is equivalent to the theoritical treatement given by Hartree.

The values of $\frac{\partial S}{\partial x}$ on each of the 4 sheets of the Riemann's surface of the equation give the up- and down-going components of the extra-ordinary and ordinary ray; the propagation depends on the position of the branch points of the surface, which is of connectivity 10. If there is a component of H in the direction of transmission, the reflected and refracted rays are not symmetrical. The possible modes of propagation are given by the integrals round the branch points on the surface (S being kept single-valued).

The President finds that a medium with parabolic distribution of ionization actually does give two definite proper values; the method gives the phase immediately and the change in the imaginary part on using the integration gives the attenuation along a ray.

La séance est levée à 12 heures.

COMMISSION III. — ATMOSPHÉRIQUES

COMMISSION III. — ATMOSPHERICS

INTRODUCTION

Les documents ci-après concernant les travaux de la Commission III, ont été mis en circulation avant ou au cours de l'Assemblée Générale (¹) :

The following papers concerning the works of Commission III were circulated before or during the General Assembly (¹).

Nº 8. — Publications Relatives aux Recherches Radioélectriques, par le Dr. J. Lugeon.
Nº 15. — Selection of Frequencies for the Recording of Atmospherics, by H. T. Friis.
Nº 16. — Atmospherics of Interstellar Origin, by the U. S. A. National Committee.
Nº 20. — A Universal Unit for Measuring Atmospherics, by H. T. Friis.
Nº 27. — Report on Radio Research in Japan, by the Japanese National Committee.
Nº 54. — Frequency Distribution of the Intensities of Radio Atmospherics, by K. A. Norton.
Nº 55. — Report on Investigations on Atmospherics carried out in Great-Britain, by R. A. Watson-Watt.
Nº 58. — Rapport sur les Recherches relatives aux Atmosphériques entreprises pendant l'Année Polaire, par R. Bureau, R. Failletaz et J. Habert.
Nº 59. — Sur la Comparaison de quelques Courbes de la Variation Diurne des Atmosphériques, par F. Failletaz.
Nº 60. — Etude des Courbes d'Enregistrement d'Atmosphériques au Scoreby Sund, par R. Bureau.

Séance d'ouverture du mercredi 12 septembre

Opening Meeting held on Wednesday, September 12th.

La séance est ouverte sous la présidence du Prof. E. V. Appleton, Président de la Commission.

The President. — The full meeting of Commission III will not take place until Tuesday next, but I hope good deal of work for our Commission will begin before Tuesday, which is near the end of the Conference. — I propose that our time this mornig be used in planning the work of the sub-commissions. — Due to the fact that much of the information, many of the papers, were received actually during the Congress, it has been impossible to have them all circulated and part of the work of the sub-commissions will be reading the documents as well as planning for international work. Therefore I propose not to follow this morning the programme for Commission III which has been circulated and so there will be no address by the President this morning. Instead we shall try to plan the consideration of the documents and fix the constitution of the sub-commissions to be formed. After spending quite a long time last night on the documents of Commission III, it seems to me that they can be grouped under the following headings :

(*a*) Origin of atmospherics
(1) Terrestrial,
(2) Extra-terrestrial.
(*b*) Propagation
(*c*) Distant Measurements.
(1) Scientific,
(2) Pratical.
(*d*) Interchange of data.

(¹) Voir résumés p. 120.

(¹) See abstracts p. 120.

Roughly speaking it seems to me that we require a sub-commission to consider all those four subjects.

With regard to Distant Measurements, there appear to be two things : first we have what one might call the scientific measurements. the measurements made, for example, to find out the origin and the direction in which these atmospherics arrive : and then, there is the purely practical problem which confronts the radio engineer, the pratical problem of specifying the atmospheric intensity with which the radio engineer has to cope in planning his wireless station. Suppose we separate this now into scientific and pratical, because if you have looked through our documents you will find we have papers on the scientific side and important practical suggestions from America, a paper by Dr. Friis. With regard to (*a*) « Origin » we are going to have communications on lightning, terrestrial and interstellar space, or extra-terrestrial. I suggest the following sub-divisions (1) terrestrial (2) extra-terrestrial.

(*b*) Propagation, we have in our documents papers by Dr. Lugeon dealing with the effect of the ionosphere on propagation.

When we come to (*c*) Distant measurements, we have important communications by the French National Committee dealing with what I might call (*c*) (1): the scientific documentation of atmospherics. That also includes not only measurements of intensity but also measurements made by Mr. Watson-Watt with a cathode radio direction finder, and important papers on pratical measurements.

I propose we should have four sub-commission to deal with these points, and I propose we leave until the end of the Conference the interchange of data.

I propose the first sub-commission on Origin should be presided over by Professor Norinder. (*Agreed.*)

Sub-Commission 2 on Propagation presided over by M. Watson-Watt. (*Agreed.*)

Sub-Commission 3, on Measurements presided over by Commandant Bureau. (*Agreed.*)

Sub-Commission 4, on Directional Reading, presided over by M. Espenschied. (*Agreed*).

I propose to leave « Interchange of data » until we have the reports of the other sub-commissions.

The members of the sub-commission 1 should pay special attention to the precise specification of the electric field emanating from a lightning flash. It is highly important that we should know something of the intensity of the field emanating from lightning, its frequency, and, if possible, its complete wave form structure.

Mr. Herd. — When delegates have been appointed as members of the sub-commissions, the National Physical Laboratory staff will then be provided from the N. P. L.

La Sous-Commission 1, Origine des Atmosphériques, est constituée par : MM. Prof. Norinder (Président), Heising, Lt. Habert, Dr. Simpson, Dr. la Cour, Dr. Schonland.

The President. — Sub-Commission 2, on Propagation should have powers to extend its survey beyond the material given in the papers here, in order to be a really useful sub-commission. I hope that it will consider that very interesting subject of musical atmospherics which were first discovered by the Engineer-in-Chief of the Post Office, Sir William Preece, certainly 40 or 50 years ago. They have been studied by Prof. Barkhausen and Mr. Eckersley, and an interesting paper has recently been written by E. T. Burton in the Bell Telephone Journal. There is another subject I hope they will consider, and that is the series of papers written by Dr. Lugeon, dealing with the effect of sunrise on the propagation of atmospherics; particularly interesting is his method of measuring the height of the ionosphere by finding the time in the morning when these atmospherics begin to make themselves evident, and I hope it will be possible for Dr. Lugeon to be a member of that second sub-commission.

La Sous-Commission 2, Propagation des Atmosphériques, se composera de : MM. Watson-Watt (Président), Dr. Lugeon, Eckersley, Dr. Jensen, Espenchied, Commandant Bureau.

La Sous-Commission 3, Mesure des Atmosphériques, est constituée du Commandant Bureau (Président), Dr. Lugeon, M. Watson-Watt, Dr. Wagner, Col. Sacco, Prof Yagi, Dr. Warsmsley, M. Espenschied, Ing. Picault, Dr. Jensen.

Répartition des documents :

N° 15 — Selection of frequencies for the recording of atmospherics. Sous-Commission 3.

N° 16 — Atmospherics of interstellar origin. Sous-Commission 1.

N° 20 — A universal unit for measuring atmospherics. Sous-Commission 3.

N° 27 — Report of Radio Research in Japan. Sous-Commission 3.

N° 54 — Frequency distribution of the intensity of radio atmospherics. Sous-Commission 2.

N° 55 — Report to Commission III on investigations on atmospherics carried out in Great Britain. Sous-Commission 4.

The President. — I would like you all to read the early part of that document because it gives the linkage we require to be discussed at the later meetings with the decisions of the Copenhagen meeting.

In addition to those documents which have been circulated I have also received two further communications from France. They arrived yesterday, and so I am afraid it has been impossible for them to be circulated. They come under Sub-Commission 3. One deals with apparatus for the registration of atmospherics, and the other is a comparison of certain curves of diagonal variation of intensities. The only important thing is to make sure that Commandant Bureau is present at the particular sub-commission which will deal with these two documents, and I think we will assign them both to sub-commission 3 of which he is President.

Le *Dr. Lugeon* demande que l'on fasse entrer la standardisation des appareils dans la sous-commission 3.

Cette proposition est admise.

The President. — Perhaps I might say a word or two about the meetings of these sub-commissions. It is of course desirable that any member of the whole Congress who is interested in the work of any of those sub-commissions should feel quite free to attend them. Also I am afraid that it will be necessary for meetings of the sub-commissions to take place sometimes during full meetings of other Commissions. In such cases members will have te decide where their time would be most profitably spent. We have only three rooms, A, B and C, at the disposal of the sub-commissions, and there will be heavy pressure on them. I propose the sub-commission on ionosphere measurements should meet this afternoon at 2.45 for an hour in room A. Some members will not feel free to come and will want to attend the meeting of Commission I. The Presidents of sub-commissions, when booking rooms, must put down the time of finishing as well as beginning.

Mr. Watson-Watt. — I think we shall be able to get further rooms at the Royal Astronomical Society. Another suggestion has been made to me for the assistance of the Presidents of sub-commissions and members, is that there should be delegated to one individual the responsability of being Secretary to the General Secretary, and M. Herd will do this.

The President. — An assistant secretary for the purposes of the sub-commissions programme only is required. Each sub-commission will appoint at its first meeting its own reporter, and it will be helpful to the secretariat if the name of the reporter were communicated as soon as possible to Captain Dorsimont.

Séance plénière du mardi 18 septembre. — Full Session held on Tuesday, September 18th.

1. La séance est ouverte sous la présidence du Prof. E. V. Appleton, Président de la Commission, assisté de M. R. A. Watson-Watt comme rapporteur.

2. *The President* opens the session with a discourse on the energy spectrum of atmospherics. Interference from this source is now regarded as possessing an energy spectrum over a wide range of frequencies, and any communication channel working on a particular frequency or band of frequencies is necessarily exposed to the interference corresponding to this range of frequencies in the atmospherics spectrum. A very useful analogy is the spectroscope of physics and there is even a mathematical analogy between the selectivity of a wireless receiver and the resolving power of the spectroscope. The practical available procedure is one in which a series of receivers is used and the spectrum of the atmospheric derived from knowledge of the reponse of the receivers.

The President then considers this method in relation to the response curve of a wireless receiver, discussing the preferable quantities to be measured and the parameters to be held constant for determination of the energy spectrum.

3. *The President* then introduces the main subject of discussion, viz, the study of lightning phenomena. Two communications are on the agenda, one a joint paper by M. Watson-Watt and himself on the nature of atmospherics as illustrated by cathode-ray oscillography, and the other by Prof. Norinder on the results of somewhat similar observations in Sweden.

4. Introducing the first paper *the President* refers to the fact that work of this kind began in the experiments of C. T. R. Wilson in 1917 and earlier, when measurements were made on the sudden change of the electrostatic field which took place when the thundercloud discharged to the ground. From the wireless point of view, however, greater interest is attached to the intimate structure of this rapid change. The work in England covered by the paper is in two sections, the first concerns with observations close to the lightning flash, carried out at King's College and the other with observations of a similar aim by with more elaborate technique to deal with more distant sources, carried out at Radio Research Station, Slough.

The President then refers to the method of photography using afterglow of fluorescence as devised by Dr. F. W. Chapman and illustrates the results obtained at different distances, e. g. up to 300 km. These agrees well with Wilson's early experiments; but detailed differences from Wilson's forms of the electrostatic field change are illustrated. At distances beyond 100 km. the radiation field alone is important and the records show a slow hump with high frequencies superimposed on it, while eventually the high frequencies become separated from the hump.

5. *Mr. Watson-Watt* continues the presentation of the paper by first summarising the whole like history of the atmospheric as revealed by the combination of the two sections of the work referred to by the President. Slides are shown illustrating the typical stages of a discharge and the nature of the field change at increasing distance from the source, continuing from the position at which the electrostatic term is becoming unimportant. Propagation takes place not in a simple homogeneous medium but in a dispersive medium, resulting in different group-velocities for different component frequencies. The higher frequencies retain higher group-velocities and are less heavily attenuated than the lower frequencies. The result is that the outrunning of the low by the high frequencies (to which the President has referred) becomes more and more obvious as distance from the source increases. At 2000 km. from the source, the separation becomes so great that

the atmospheric is composed of two completely separate parts, a high frequency component of the order of 5.000 c/sec. followed, after a period of no sensible field change, by a tail containing components of the order 500 c/sec. It is still a matter of investigation whether there is a relatively very small content of intermediate frequencies, say, 1.000 to 5.000 c/sec. in the original·impulse or whether dispersive action includes specially heavy selective absorption in this band. The speaker then discuss differences of amplitude with distance, referring to the fact that the presence of a conducting region modifies the law of spreading from the spherical spread of the earlier stage to the cylindrical spread of the later stage. Other slides are shown, one collating the data, as available at the moment, for the maximum amplitudes of the two important components of the field change, while another reproduces oscillograms made to a more open time scale illustrating substantial identity in complex fine structure between two successive atmospherics separated by 66 seconds. Lastly reference is made to the fact that there is evidence that the attenuation of the high frequencies depends not only on distance but also on the actual path, as shown for example, by considerable differences on the paths from an Atlantic source to Slough and Leuchars respectively.

6. In discussion of the paper, *Mr. Heising*, says that there appears to be a gap in the spectrum and suggests ionised hydrogen in the earth's magnetic field as an absorbing agency for frequencies round about 1800 c/sec. He also enquires whether there is any difference in frequency as received from different distances.

Mr. Watson-Watt replies that the possible explanation by hydrogen ions has been considered, but that there is great difficulty about finding any other evidence of, and in accounting for, the free hydrogen. In regard to the query about high frequencies, the predominating frequency, i. e. that with the highest relative amplitude and that which arrives first, is definitely higher the greater is the distance from the source.

Dr. Whipple and *Prof. Wagner* also join in the discussion.

7. *Le Prof. Norinder* donne ensuite un aperçu de la deuxième communication dont un nombre limité de copies sera disponible ultérieurement.

Les enregistrements montrés ont été obtenus à l'aide d'un oscillographe cathodique à grande vitesse et les observations sont continuées. Le Prof. Norinder montre des clichés des appareils et des installations; on utilise deux oscillographes, l'un comme indicateur, l'autre comme enregistreur. Il montre aussi des enregistrements illustrant les résultats obtenus, ceux-ci comprennent une table de fréquences des atmosphériques, des formes oscillatoires ou unipolaires, des polarités différentes, des enregistrements à temps de base lents ou rapides ainsi que le rapport entre l'allure des ondes de claquement et celles des ondes de grincement comme on les entend dans un récepteur ordinaire.

8. On décide de nommer une Sous-Commission supplémentaire pour discuter la recherche de la direction des atmosphériques et pour préparer des résolutions sur ce sujet, à soumettre à l'approbation de la Commission lors de la séance de clôture.

Cette Sous-Commission 4 comprend : MM. R. A. Watson-Watt (Président), Commandant R. Bureau, Prof. H. Norinder, Prof. Dr. K. W. Wagner, Dr. Lugeon.

Séance de clôture du mercredi 19 septembre.

Final Meeting held on Wednesday, September 19th.

1. La séance est ouverte sous la présidence du Prof. E. V. Appleton, assisté de M. Vigoureux comme rapporteur.

2. *The President.* — The first business this morning is to receive and consider the reports prepared by our sub-commissions. In order that you can see exactly how we arranged our work, I have written on the black-board the names of the four sub-commissions and the names of the gentlemen who presided.

Sub-Commission 1 : Origin, Prof. Norinder.

Sub-Commission 2 : Propagation, M. Watson-Watt.

Sub-Commission 3 : Measurements, Commandant Bureau.

Sub-Commission 4 : Directional Recording, M. Watson-Watt.

3. *Prof. Norinder.* — La Sous-Commission désire présenter les résolutions suivantes à la Commission III.

(Le Prof. Norinder lit les résolutions (¹) qui sont traduites en français par M. Vigoureux).

The President. — Thank you Prof. Norinder and our translator.

Dr. Whipple. — With regard to resolution 5, I think that this draft does not bring out the intention which is, I gather, to make use of records which have been made already and which are in course of production in the routine of magnetic observations. Observatories which are provided with the la Cour magnetograph have been recording lightning flashes in their neighbourhood quite unintentionally, and I gather the intention as that these records should be examined systematically and the number of such disturbances should be counted and used for statistical purposes. « By suitable recording » does not seem to me quite the same as « by the analysis of existing records ».

The President. — Do I understand you correctly, Dr. Whipple, in that I think you would prefer to have some record made of the work already in progress ?

Dr. Whipple. — That was the moral, I think, to be drawn from the records which Dr. la Cour produced. During the Polar Year all these observatories had la Cour Magnetographs. They have recorded these disturbances and something could be made of them.

The President. — You would not only consider analysis of existing records but it would be extended in the future.

Dr. Whipple. — I do not think that the suggestion is put forward that anyone should go to special expense in making magnetic records of disturbances, it is purely a matter of making use of the recorders in use in the Polar Year.

The President. — Dr. Whipple, could I ask you to suggest an amended form for resolution 5 ?

Dr. Whipple. — « By the analysis of magnetic records which showed the effects of lightning ». I do not know any harm in a specific reference to the la Cour magnetograph. For example, « obtained with the la Cour magnetograph ». « The Committee is of the opinion that the magnetic observatories throughout the world can make important contributions to statistical research on thunder storms by the analysis of magnetic records showing the effects of lightning ».

Mr. Watson-Watt. — I do not wish to oppose the amended wording, but I did not bring from the discussion the same impression as Dr. Whipple has brought, nor did Prof. Norinder share the impression that what was specially invisaged was analysis of previouly existing records. My impression was that these records were produced to demonstrate that future work would be of

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(¹) Voir p. 73.

great value. It is true that the amended wording leaves the future as well as the past permissive, but in the absence of Dr. la Cour I am not able to interpret his intentions, (he was the mover of the resolution) but I do feel it should be clearly indicated that we did hope that when magnetic instruments are working in a suitable situation and the opportunity offers, the magnetic record should be specially examined with reference to the other data about the place of discharge of the lightning, which I rather feel may not be available in all the cases of the past records during the Polar Year.

Prof. Norinder. — Je suis complètement d'accord avec ce qu'a dit M. Watson-Watt.

The President. — It remains to vote on the matter. We will take the amendment first. 4 for, 2 against. The amendment is carried. We accept the change in the text given by Dr. Whipple.

Paragraph 5 « by the analysis of magnetic records showing the effects of lightning ».

Commandant Bureau. — Avant de prendre une décision définitive, ne pourrions nous pas attendre l'arrivée du Dr. la Cour qui sera ici avant la fin de la séance ?

The President. — I do not think that is possible. This meeting is a definite meeting.

M. Shaughnessy. — Add a paragraph to this effect ? « and work in this direction can be continued ». The amendment does not limit it to the comparison with past effects, but if there is any doubt « that the subject can be continued ».

The President. — Can I put the whole document to you as a whole and put it that these recommendations to Commission III be adopted ? (*Adopted.*)

In each case it seems to me very desirable to have some standing sub-commission that might act or draw the attention of other bodies to these resolutions. They are all statements that certain things are very desirable, and if we merely put these things on paper without having somebody to act as propagandist, perhaps we may not get much further. We might have a sub-commission which will collect information of this type, draw the attention of groups of interested workers to work of similar character going on in different parts of the globe. I suggest that Prof. Norinder act as the President of a standing sub-commission to draw the attention of interested bodies to this particular programme, and also to report at our next meeting on the work which has been done in the interval. (*Agreed.*)

Let us consider the other members of the sub-commission. Perhaps three might be a desirable number. Prof. Norinder (President) M. Watson-Watt, Dr. Schonland. (*Agreed.*)

4. *Mr. Watson-Watt,* President of Sub-Commission 2, on Propagation, reads the proposals of his Sub-Commission.

One resolution (¹).

The President. — This now is before you for further discussion.

Prof. Wagner. — Would it not be wise to include further European countries ?

The President. — Would you agree to include « the extension of such work already in progress in North America and Japan ». I suggest « Europe and Japan ».

Dr. Rayner also makes some suggestions.

The President. — It is suggested to me by Dr. Goldschmidt that we delete the word « south ». In other words, we should like to see observations carried out in the whole of Africa.

It is suggested that the paragraph should read as in the text except that there are two deletions: one is in the last line but one « in North America

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(¹) See p. 116.

and Japan » suggested by Dr. Rayner; and the word « south » (first) in the last line, at the suggestion of Dr. Goldschmidt.

The President — reads the amended resolutions and suggests substitute « now being conducted » for « now in progress ».

Mr. Shaughnessy proposes to leave out « already ».

The President. — The resolution will now read « ..... is of the opinion that the extension of such work and its initiation in Africa and South America....... »

Dr. Smith-Rose. — Is the wording quite suitable ? It is not worded as a recommendation. I suggest in the second half « and récommends », the sentence would thus run as follows : « The Commission, having reviewed the distribution throughout the world of the stations at which fundamental investigations on atmospherics are now in progress, recommends the extension of such work and its initiation in Africa and South America as of special importance ».

The President. — Recommendation is *agreed.* It does not seem necessary to have any standing committee to consider this particular point. (*Agreed.*)

Commandant Bureau. — La première sous-commission qui vient d'être désignée peut s'occuper de cette question.

The President. — I think, Comm. Bureau, this might very well come under your sub-commission. It seems to me to have closer connection with your sub-commission on measurements of armospherics. Perhaps later on the sub-committee 3 will take care of this as well.

5. *Commandant Bureau,* Président de la Sous-Commission 3, des Mesures, lit les deux résolutions (¹).

Dr. Whipple. — 24-27 in the first resolution looks strange, I think we should have some justification for that rather wavering decision.

Commandant Bureau. — L'indication 24-27 Kc/s tient compte à la fois des propositions anglaise (24 Kc/s) et française (27 kc/s). La Sous-Commission estime qu'il n'y a guère de différence dans les enregistrements obtenus sur les diverses ondes de cet intervalle et que de plus une certaine liberté doit être laissée pour permettre de choisir une onde libre de brouillages.

Mr. Watson-Watt. — These figures must not be regarded as sacred numbers. It will inevitably be necessary for individual workers to operate at different frequencies owing to the fact that they are radio telegraphy signals we shall be using for atmospherics.

The President. — The Sub-Commission does not signal out these frequencies in order of preference, because it may be possible that some particular nation can only attempt recording on one frequency. I do not know whether it is desirable that the frequencies should be the same in different countries, but suppose I had this put before me, I would not know quite what I could do unless I could do the lot.

Commandant Bureau. — Cette question n'a pas été discutée par la Sous-Commission, mais l'opinion des différents membres était que l'heure n'est pas venue d'imposer un ordre de préférence. Suivant le but que l'on poursuit et suivant les facilités locales de lutte contre les brouillages, une onde pourra s'imposer plus que l'autre. Pour parler à mon point de vue personnel, je donne actuellement la préférence à l'onde de 27 kc/s, mais je comprends très bien que diverses circonstances puissent amener d'autres chercheurs à ne pas donner la priorité à cette onde. Je signale cependant le grand nombre de documents déjà recueillis en Pologne, France, Afrique et dans les régions arctiques sur 27 kc/s ou sur une onde voisine.

(¹) Voir p. 117.

The President. — Perhaps that point is not so very important because the second resolution is that a permanent sub-commission be organised to deal with the work. We might leave question of preferential frequencies to the sub-committee we are going to appoint.

Prof. Wagner. — I should be more in favour to indicate the frequencies now at which the work should be done. We have not fixed that point in the sub-commission, but so far as I am aware many of these observations have been made on the long wave 24 or 27 kc/s. We have in the past collected a big material of that kind and we may find it important to continue records on this frequency, especially for the reason of getting material from far away.

Commandant Bureau. — Je suis d'avis que les fréquences de 24 à 27 kc/s sont les plus indiquées si l'on donne un ordre de préférence.

Dr. Lugeon. — Je préfère 27 kc/s que l'on a déjà utilisée en Suisse, en Pologne, en Norvège, au Sahara et dans les Iles des Ours.

On pourrait ajouter à la résolution 1 : « Preference should be given to the frequency of 27 kc/s which has already been used extensively for such records ».

Mr. Watson-Watt. — I suggest we again go back to 27 kc/s.

The President. — The full sentence : « The series of frequencies of approximately 12, 27, 60.... kc per second be adopted for the recording of atmospherics. Preference should be given to recording at 27 kc per second ».

Now you have the suggestion : nº 1 as altered, nº 2 unaltered. (*Two resolutions adopted.*)

To appoint permanent sub-commission to organise in accordance with resolution 2 the recording of atmospherics in such a way that the rate of generation of electric disturbances... » Comm. Bureau (President), Dr. Lugeon, M. Watson-Watt. (¹) (*Agreed.*)

I would like to keep that sub-commission quite small.

That concludes the work of Sub-Commission 3.

6. *The President.* — *Sub-Commission* 4 which, you will remember, was formed after our full session of Commission III under the presidency of Mr. Watson-Watt.

Mr. Watson-Watt reads the three resolutions of sub-commission 4. They are adopted in their definitive form (¹) after some discussion.

The President. — Now we have to form our Sub-Commission.

Dr. Lugeon. — J'aimerais profiter de cette occasion pour adresser officiellement mes remerciements chaleureux au Comité National Britannique pour les remarquables efforts qu'il a faits en transmettant ses observations goniométriques des foyers de parasites atmosphériques. Ces travaux furent d'une grande utilité pratique et théorique et contribuèrent à fixer nos idées sur l'origine terrestre des parasites.

The President. — It means thanking Mr. Watson-Watt, the Secretary of our Commission.

I propose for the Sub-Commission : Mr. Watson-Watt as President and Comm. Bureau.

Mr. Watson-Watt. — My Commission was unwilling to tie the hands of this Commission by making formal nominations, but we did consider for this purpose it might be desirable to have a slightly larger committee than the others, and its members should include Comm. Bureau, Dr. Lugeon, Prof. Wagner, Prof. Norinder, Dr. Schonland, and an American delegate who might perhaps be suggested by Dr. Jensen.

The President. — It seems to me there is a good deal to be said for this in view of the wide nature of the object you desire. We might appoint the members suggested by Mr. Watson-

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(¹) See p. 117.

(¹) See p. 117.

Watt and give him permission, as President of this Sub-Commission, to co-opt additional members from other countries when desirable. (*Agreed.*)

La Sous-Commission sera composée de MM. Watson-Watt (Président), Comm. Bureau, Dr. Lugeon, Prof. Norinder, Dr. Schonland, Prof. Wagner, Prof. Friis.

7. *The President.* — Having come to the end of our work we had planned, we left over the question of interchange of data. I believe Mr. Watson-Watt has a communication to make on this subject.

Mr. Watson-Watt. — I should like to refer to the subject which has already been mentioned by Dr. Lugeon. In the Copenhagen Assembly the British National Committee was asked to arrange for the supply of daily reports on the position of the predominant sources of the atmospherics, to be transmitted to Paris for inclusion in the Ursigrams radiated from Paris. The work was undertaken by the Department of Scientific and Industrial Research on the recommendation of the Radio Research Board, but the Radio Board limited its undertaking to the transmission of the data for one year of experiment in order that it might, at the end of that year, review the evidence as to the utilisation and the usefulness of such data to workers in other countries. The Board was particularly anxious, I think, to find out whether the transmission of the data by radio telegraphy was an important factor in its usefulness. And I may recall to you the fact that in our report to Commission III, document 55, we have in Appendix (1) given the history of this particular transaction, ending with the statement that the data do not in fact reach the United States. The Appendix will be supplemented by Dr. Lugeon's remarks and these are the only communications we have as to whether the past work was useful and as to whether there was any desire that the substantial organisational efforts for its continuance are desired by this Union.

The President. — It seems to me there are two questions involved : first whether this kind of information should be contributed by a Radio Ursigram or interchanged by private arrangement between the workers in question.

Dr. Lugeon. — Je considère l'échange des données radiogoniométriques sur les parasites d'une grande importance. Toutefois, je constate que l'émission régulière de ces repérages par les Ursigrammes coûte beaucoup de travail à nos amis Anglais. Comme peu de radiophysiciens utilisent actuellement ces azimuts de foyers de parasites, je me demande si l'on ne pourrait pas se contenter d'un échange temporaire par écrit, ainsi que nous le faisons pour les courbes d'enregistrement de la fréquence par minute des parasites.

Prof. Norinder. — Je suis d'avis que ces Ursigrammes ont une grande importance. On pourrait agir ainsi dans des cas particuliers lorsque l'on désire avoir très rapidement des informations détaillées. On pourrait arriver à une convention pour alléger la besogne, soit en envoyant des câblogrammes nocturnes et, par conséquence, recevoir très rapidement les renseignements.

Prof. Wagner. — I should like to assist the opinion expressed by Dr. Lugeon that it would be of great value for scientific people to have this information in a correlated form by letter from time to time. Most of my German colleagues are not in a position to provide for regular reception of Ursigrams, but they would appreciate very much to get this information every week or fortnight or oven once in a month for scientific studies, comparing purposes, etc.

The President. — I know information has been sent by Mr. Watson-Watt to Dr. Schindelhauer at Postdam.

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(1) See p. 187.

There is one point. It seems to me preferable to leave this matter open in this respect. If these things were prepared and sent round by post, it would perhaps mean for more work than if special cases were dealt with separetely. It seems it is far better for each National Committee to tell workers in his own country that this kind of information is available and then arrange for direct communication from that person with his special needs to the other person who can give him the information. I suggest that we might appoint Mr. Watson-Watt as our representative in matters concerning interchange of data and that he will be good enough to assist the workers under this Commission in this respect.

Prof. Norinder. — Je suis complètement d'accord avec cette idée.

The President. — It seems to me that Mr. Watson-Watt has full knowledge of all information available. Any worker who desires certain data might very well communicate with him, and I am sure he will do his best to put him in possession of the data he requires.

Dr. Goldschmidt. — Le Secrétariat Général se mettra à la disposition de tout le monde.

The President. — All the Commissions will note that the Secretary General is at their disposal for distributing information.

Dr. Lugeon. — Je propose qu'une copie de tous les documents échangés entre les membres des sous-commissions soit adressée au Secrétariat Général afin d'être gardée dans les archives de l'U. R. S. I.

Dr. Goldschmith. — Le Secrétariat Général pourrait communiquer ces renseignements aux autres membres qui en exprimeraient le désir.

The President. — There may be some very wide-spread desire for certain data, in which cases the person who has the data would not distribute it himself. Then the Central Office at Brussels is the correct medium for such distribution.

Comm. Bureau. — Il convient de faire une séparation entre deux genres de renseignements. Pour les uns il serait désirable de les voir passer par l'Office Central, les autres seraient ceux pour lesquels les renseignements devraient être envoyés rapidement à certains membres.

Dr. Goldschmidt. — Je crois qu'il faudrait envoyer au Secrétariat Général des copies de toutes les informations échangées, car ce qui à un moment intéresse deux personnes, peut à d'autres moments en intéresser plusieurs.

The President. — That is very important. All the sub-commissions, if they do any work, will send copies of all work carried out and decisions to the Secretariat General.

That concludes the business. It now remains for me to thank the members of Commission III, to thank especially our Chairmen and the members and all of you for having worked so well and put up interesting resolutions. I am particularly glad to find them not too ambitious. All the resolutions put forward look to be within our grasp, so we hope at the next meeting of the Commission (at the Assembly General) we shall be able to consider a rich harvest of data gathered by the methods we have decided on to-day.

I thank you all, gentlemen, very much indeed.

La séance est levée.

Sous-Commission 1. — Origine des Atmosphériques

Sub-Commission 1. — Origin of Atmospherics

Séance du samedi 15 septembre. — Meeting held on Saturday, September 15th.

La séance est ouverte à 9.45 heures sous la présidence du Dr. NORINDER, Président de la Sous-Commission, assisté de M. F. E. Lutkin comme rapporteur.

2. Assistent à la séance: MM. Le Commandant Bureau, Prof. S. Chapman, Prof. C. L. Fortescue, Ing. S. Gejer, Lieutenant de Vaisseau Habert, R. A. Heising, J. F. Herd, Prof. Jouaust, Dr. la Cour, Prof. Mimno, Ing. Picault, Colonel Sacco, Dr. Schonland, Scrase, Dr. Simpson, R. A. Watson-Watt, Dr. Whipple.

3. *Le Président* déclare que les principaux problèmes à étudier sont ceux se rapportant aux difficultés associées à la détermination de l'origine des atmosphériques et à la mesure précise des décharges électriques sources de ces phenomènes. Il mentionne les travaux de Bureau et de Watson-Watt, d'après lesquels les sources ont été définitivement localisées dans les régions d'activité orageuse ou dans celles où une telle activité est prévue. Lui-même, est d'accord avec ces chercheurs pour trouver des relations étroites entre les décharges des éclairs observés et les atmosphériques.

4. En ce qui concerne les mesures de décharges électriques, il a l'impression que l'oscillographe à rayon cathodique est le seul appareil qui puisse être utilisé avec succès, et qui puisse fournir des enregistrements de très rapides variations du champ enregistré. Parmi 7500 observations, il a rencontré de nombreux cas pour lesquels on a observé des décharges répétées sur un simple temps de base de 1/100 seconde, et à l'aide de bobine de champ, il mesuré le secteur magnétique du champ et trouvé, associés à ces décharges, des courants de l'ordre de 2 à 27 Ka/micro-sec. Il pense que la méthode à suivre pour étudier ce côté de la question, consiste à observer un orage qui s'approche, à l'enregistrer d'abord sans amplification, et, quand l'orage s'éloigne de la station, à effectuer des enregistrements avec une amplification augmentant graduellement et à l'aide d'une communication téléphonique, tout en annotant les distances auxquelles se produisent les décharges. Il pense qu'un gain d'environ 60 db. suffit pour suivre les décharges aux grandes distances. Il a des possibilités d'installer quatre équipements mobiles convenant pour des essais de ce genre. Un de ces équipements est déjà en service depuis huit mois.

5. *Dr. Simpson* states that he thinks it was agreed that lightning flashes were producers of atmospherics but he would like to have opinions as to whether every atmospheric is produced by visible lightning flashes or are there conditions in the atmosphere in which atmospherics could be generated without visible lightning.

6. Le *Commandant Bureau* discute des résultats goniométriques obtenus en France et signale qu'ils conduisent eux aussi à une conclusion analogue, c'est à dire à une origine météorologique des atmosphériques. Même pour les atmosphériques enregistrés sur ondes longues et qui viennent de très grandes distances, on peut procéder à une comparaison avec les observations météorologiques relatives aux régions où se localisent les sources d'atmosphériques; si des orages ne sont pas toujours signalés dans ces régions (ce qui peut d'ailleurs souvent provenir d'une lacune dans les réseaux d'observation météorologique), la situation météorologique qui y règne est cependant toujours favorable au développement d'orages.

La vérification de cette relation entre les zones orageuses et les sources d'atmosphériques est donnée d'une manière frappante dans un exemple dont le diagramme est mis en circulation. Une perturbation météorologique parcourt la France de la Bretagne à la Lorraine en passant au Nord du goniomètre (à Paris). L'emplacement et l'heure des orages successifs qui l'accompagnent ont pu être déterminés d'une manière très précise à l'aide d'un réseau très dense d'observateurs. La concordance entre ces observations et les données du goniomètre se poursuit dans les détails montrant que les sources d'atmosphériques coïncident avec les perturbations orageuses. Par contre, le nombre d'éclairs observés est nettement plus faible que celui des atmosphériques enregistrés sur le goniomètre et correspondant à la source jumelée à l'orage. Cependant le goniomètre est un appareil à secteur étroit ouvert seulement sur 1/20 de la circonférence et le nombre d'atmosphériques qu'il capte n'est donc que le vingtième du nombre total.

Le Commandant Bureau conclut que, dans certaines perturbations météorologiques, il se produit peut-être beaucoup d'atmosphériques qui ne sont pas accompagnés d'éclairs visibles. Dans d'autres, au contraire, les atmosphériques coïncideraient toujours avec des éclairs. Il y aura peut-être là un moyen de discriminer des perturbations météorologiques orageuses de caractères différents.

7. Le *Colonel Sacco* déclare que très peu a été fait en Italie et qu'aucune vraie radiogoniométrie n'a été entreprise, mais le peu que l'on a fait montre que la plupart des parasites atmosphériques reçus à Rome viennent du S-E ou du N-O, au-dessus des étendues terrestres. On en a enregistré très peu venant des étendues maritimes. Les deux observatoires du Mont Casino et de Florence sont maintenant pourvus de radiogoniomètres, et on espère pouvoir communiquer des résultats à la fin de l'année.

8. *Mr. Watson-Watt* states that in the case of similar recording in England, as technique advanced, fewer cases were recorded when atmospherics appear to come from areas were thunderstorms were not probable, and he hopes to show to the Sub-Commission on Propagation of Atmospherics, charts showing the close fit between sources and storm areas, and also one or two cases in which atmospheric appears to come from areas of clear sky conditions with no rain. In particular one case in the Adriatic was of especial interest.

Le *Commandant Bureau* montre un diagramme dans lequel des atmosphériques violents en direction du Sud-Est ne correspondaient apparamment à aucune perturbation orageuse des cartes météorologiques. Mais en utilisant des documents d'observations plus complets il a pu vérifier l'existance d'orages en Italie dont l'absence sur les cartes provenait d'une lacune dans la documentation qui avait servi à les établir.

9. *Dr. la Cour* produces magnetic records taken when thunderstorms were occuring within some 10 km of the observatory showing characteristic oscillations. In the case of records at Copenhagen, a single impulse was indicated accompanying the flash, while in a record taken in Australia, a succession of impulses was suggested.

10. *Le Président* déclare qu'il a constaté l'existence d'atmosphériques produits par des étendues nuageuses dans lesquelles le champ électrostatique n'était pas suffisamment développé pour produire la lueur de l'éclair.

11. *Dr. Simpson* says it has hitherto been thought that as the thundercloud developed, there is a separation of charges until the breakdown potential is reached. It now appears as if, while separation proceeds, there is a series of small local discharges each giving rise to an atmospheric, probably not large, and building up to the final flash. The physics of such a process is difficult; even in a cloud, large fields would still be required for local discharges, and it is difficult to see how these could be set up without also setting up a field so great as to give a large discharge.

12. *Dr. Whipple* suggests that more stations be set up with point-discharge apparatus as at Kew, to record changes in the electric field, the cost of the installation being quite small. Replying to a question of the Chairman, he says the time scale in use at Kew is 1 cm/min.

13. *Dr. Schonland* feels the need of accurate observations correlating atmospherics with observed lightning. Listening with a 3-valve set and with observers registering flashes on a tape he has found many atmospherics where no flash had been observed.

He suggests that observers might have missed seeing flashes to the upper air. He only knows of two cases in litterature where such upward flashes have been seen.

Dr. Simpson quotes Schuster as seeing flashes upward into clear air when above cloud system and the Chairman and Dr. La Cour both record having seen similar phenomena.

Dr. Schonland continuing, suggests a different constitution of atmospherics generated by storms during the day and during the night. In South-Africa photographic methods are used to study flashes and he suggests that the infrared photography may enable flashes within the cloud to be recorded. Co-operation of oscillographic workers with this work is required.

15. *Dr. Whipple* suggests that much may be learned from aural observations with an ordinary broadcast set.

Prof. Fortescue says that using a large aerial and high values of set-gain it is almost impossible, with near storms, to hear silent periods between flashes, but,

Mr. Watson-Watt points out that the brush discharges from high aerials when a charged cloud is near probably vitiate all such aural observations. Frame aerials clear of all large conductors are alone suitable. He then summarises the general conclusions from the work on the wave-form of atmospherics at Slough to be reported to the Full Session of Commission III, and says it is now possible to determine approximately whether an atmospheric is of distant origin or not, by its wave form.

16. *Mr. Heising* draws attention to Document A. G. 1934/N° 16/Comm. III (¹) suggesting the existence of atmospherics of interstellar origin and points out the desirability of participation in this work by some equatorial station or one in Southern Hemisphere to determine more accurately the direction in space of the sources. Details of the apparatus used are to be found in Proceedings of the Institute of Radio Engineers, December 1932.

17. La séance est levée ; au cours de la prochaine réunion qui aura lieu le 17 à 9.45 heures, on discutera les résolutions à soumettre à la Séance Plénière de la Commission III.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

La séance est ouverte à 9.45 heures, sous la présidence du Dr. Norinder assisté de M. F. E. Lutkin comme rapporteur.

Le *Président* déclare qu'il a reçu diverses résolutions à soumettre à l'examen de la Sous-Commission.

Ces résolutions sont discutées et celles à présenter à l'approbation de la Commission III en Séance Plénière, sont établies comme indiqué ci-après.

1. The Sub-Commission recommends that optical and photographic recording of lightning flashes should be pursued and developed as much as possible, in such a way as to furnish a precise basis for the study of the role of lightning as a source of atmospherics.

2. The observations envisaged in Resolution 1 which would be principally directed to the

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(¹) See p. 137.

study of the regions of thunderclouds involved in lightning discharges and of the time-relations of the elements of the discharge would, in the Sub-Commission's opinion, be greatly increased in value by simultaneous observations of changes in the électric field.

3. The Sub-Commission is of opinion that the magnetic observatories throughout the world can make important contributions to statistical researches on thunderstorms by suitable recording of the magnetic effects of lightning.

4. That it is desirable that apparatus for recording potential gradient and apparatus for recording point-discharge be installed at numerous places so that the changes in the electric field may be compared with the incidence of atmospherics.

A scale of 5 mm. to one minute is recommended for such records.

5. The Sub-Commission is of opinion that further studies of the problem of electrical, disturbances of apparent extra terrestrial origin should be made, and that observations should be made over an extended range of frequencies, especially higher frequencies, and at a number of places in both hemispheres.

Sous-Commission 2. — Propagation des Atmosphériques

Sub-Commission 2. — Propagation of Atmospherics

Séance du lundi 17 september. — Meeting held on Monday, September 17th.

1. La séance est ouverte à 11.30 heures, sous la présidence de M. R. A. WATSON-WATT, Président de la Sous-Commission, assisté de M. A. F. Wilkins comme rappoteur.

2. Assistent à la séance : MM. le Commandant Bureau, Prof. Chapman, T. L. Eckersley, L. Espenchied, Lt. de Vaisseau Habert, Prof. Hackett, J. F. Herd, Dr. J. Lugeon, F. E. Lutkins, Prof. C. Manneback, Prof. H. Norinder, Dr. Schonland, Scrase, Dr. V. van der Pol, Prof. Dr. K. W. Wagner, Dr. F. T. W. Whipple.

3. *The President* in opening the meeting, suggests that tropospheric origin should be assumed, and that the subject may be considered under the headings :

1. The influence of incidents of travel on the received wave form.
2. The Application of Dr. Lugeon's method of recording atmospherics to investigation of their propagation.
3. The frequency distribution of atmospherics at the receiving station.

4. *The President* then proceeds to explain the shape of field changes obtained by recent records in England, revealing increased temporal separation between high-frequency and low-frequency components with distance. It is important to this Committee to consider how the component frequencies traverse the medium with group velocities which are functions of frequency. This is illustrated by records of the fields observed at different distances, with examples of increasing temporal separation between the high-frequency and low-frequency components of the radiation field. He asks is it necessary to consider the ionosphere for explanation of the separation or is substantial change of group-velocity with frequency to be expected from the lower atmosphere. The subject appears to be associated with that of « musical atmospherics ».

5. *Mr. T. L. Eckersley* outlines the available knowledge of « whistlers » or « musical atmosperics ». As observed aurally, their indication is in the form of a note descending from about

4000 c/sec. to about 200 c/sec. and lasting about one second. Occasional series follow each other at intervals of 1 or 2 seconds and, in some cases, groups start with loud checks followed by successive whistlers, covering a total period of 30 to 40 seconds, each whistler more long-drawn-out. Their directions agree with these of atmospherics of ordinary terrestrial origin. It seems probable that there is some change of form in transmission through the ionosphere, so that this problem appears to be related to the first (described by the President). Experimental data are mostly from aural observations, but synthetic oscillographic records have been made by Burton and Boardman of the Bell Laboratories. The phenomenon is generally a low-level one, approximating to that of noise level.

6. *Prof. Wagner* reminds the meeting that the phenomenon of different group velocities with frequency is well-known in telephonic transmission through loaded cables over long distances, where low frequencies arrive first giving ascending tone.

Au cours d'une discussion générale, le *Prof. Manneback* émet l'idée qu'il doit exister deux parcours, un pour les basses fréquences et l'autre pour les hautes. Peut-on retirer des observations expérimentales une preuve de l'existence de ces deux parcours ?

Mr. Watson-Watt shows a curve on which logarithm of distance is plotted against time, the resultant graph being approximately a straight line.

Mr. Eckersley points out the similarity to the propagation of earthquake phenomena which Mr. Watson-Watt stated, has already been observed.

7. *Dr. van der Pol* reminds the meeting that the matter referred to Committee of Commission II (Interaction of Radio Waves) might also be of importance. The conclusion meantime is that of a non-linear effect in the ionosphere, and suggests that atmospherics of large amplitude might impose a modulating effect on carrier waves. Their propagation via the ionosphere might then be influenced by the existence of a carrier frequency and they might give different results according to whether a carrier is present or not.

8. Le *Dr. Lugeon* ouvre la discussion au sujet du second point à examiner, et il montre des courbes d'activité d'atmosphériques à ondes longues établies en fonction du temps; ces courbes accusent une brusque chute de l'activité au lever du soleil, la chute est particulièrement remarquable pour les ondes très longues.

Le *Dr. Lugeon* déclare que cela provient des changements d'ionisation se produisant au lever du soleil dans l'ionosphère. C'est un effet remarquable auquel il faudrait donner un nom. Il montre également un abaque permettant de déterminer en tous les endroits du monde le moment du lever et du coucher du soleil au sol et dans la couche Kennelly-Heaviside (100 km. de hauteur). Cet abaque lui permet de calculer l'angle d'incidence sur l'horizon de la génératrice du cône de réfraction des atmosphériques dont le sommet est le récepteur et la base, la couche Kennelly-Heaviside. L'angle d'incidence des atmosphériques varie de 2 à 13° (il dépend de la fréquence d'enregistrement). Un autre résultat est le moment de la chute de l'activité vers le lever du soleil, cette chute se produisant plus tard aux basses fréquences (¹).

9. *Mr. Espenschied* introduces the third subject, listed above, stating that the results of measurements of atmospherics by the American Telephone and Telegraph Compagny were presented as a part of the material submitted to the Madrid Conference on Telecommunications of 1932 by the United States. These were in the form of day and night curves of the distribution of atmospherics with frequency. This material was published in a paper by Mr. Potter, as indicated in the first footnote of M. K. A. Norton's paper. Mr. Norton's paper, in effect, takes

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(¹) *C. R. Paris*, t. 199, p. 1059, 1934.

this material and attempts to account for it on a theoretical basis. He arrives at curves for the frequency range up to 5000 cycles, indicating the distance from the receiving station within which most of the atmospherics originate. A very brief discussion follows.

10. *The President* in summing up the discussions, asks if the most useful work of the Committee would not be the suggestion of small sub-committees on each of the three subjects.

Prof. Wagner thinks it would be unsatisfactory not to arrive at some form of conclusion and suggests resolutions on some of the general problems.

11. La Sous-Commission convient de se réunir le même jour à 16.15 heures pour établir les résolutions à soumettre à l'approbation de la Commission III.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

1. La séance est ouverte à 16.15 heures, sous la présidence de M. R. A. Watson-Watt, assisté de M. A. F. Wilkins comme rapporteur.

2. *The President* announces that he has discussed the question of whistlers with Mr. T. L. Eckersley and that they are of opinion that the time is not yet ripe for the submission of any formal resolution on the subject.

3. *Dr. Schonland* submits a tentative resolution to enable him to approach the South African Government for support in the atmospherics work in that country.

Le *Dr. Lugeon* pense que la résolution pourrait être rédigée comme suit « Hémisphère Sud et particulièrement en Afrique du Sud ».

Mr. Espenschied thinks that an inadequate amount of work on the directional characteristics of atmospherics has been done in the United States and that more is desirable.

The President suggests that Dr. Schonland's original resolution should read.

« The Committee having reviewed the distribution throughout the world of the stations at which fundamental investigations on atmospherics are now in progress, is of the opinion that the extension of the work in North America and its initiation in South Africa and South America are of especial importance ».

The President says that, in his own work, he has often felt the need for such results as would be obtainable if this recommendation was put into practice.

The resolution is put to the meeting and carried.

4. *Mr. Espenschied* suggests that since the Pacific represents a large area in which relatively little atmospheric work has been done, and since Japan is geographically in a position to observe conditions in the Western Pacific, it might be desirable to include in the resolution a mention of Japan.

The President suggests bracketing North America and Japan in the foregoing resolution.

This is agreed, and the resolution for submission to the Full Session of the Commission was therefore worded as follows :

« The Commission, having reviewed the distribution throughout the world of the stations at which fundamental investigations on atmospherics are now in progress, is of the opinion that the extension of such work already in progress in North America and Japan and its initiation in South Africa and South America are of especial importance ».

Sous-Commission 3. — Mesure des Atmosphériques

Sub-Commission 3. — Atmospheric Measurements

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

La séance est ouverte à 14.30 heures, sous la présidence du Commandant Bureau, Président de la Sous-Commission, assisté de M. Page comme rapporteur.

Assistent à la séance : MM. Espenchied, le Lieutenant de Vaisseau Habert, Dr.J.Lugeon, Lutkin, Hackett, Cdt. Matteini, Dr. Norinder, Dr. Schonland, Dr. Wagner, Watson-Watt, Whipple, White et Prof. Yagi.

Le Président ouvre la séance en donnant un résumé des méthodes non-directionnelles et directionnelles, employées actuellement pour la mesure du niveau moyen des troubles atmosphériques; la première catégorie peut être divisée en méthodes électriques (qui consistent dans la mesure de la charge accumulée dans un condensateur) et en méthodes mécaniques fournissant un décompte du nombre de fois que les atmosphériques se produisent. Dans les deux cas, il est essentiel de fournir une spécification convenable des appareils afin de pouvoir interpréter et comparer les résultats; ce qui peut facilement être fait à l'aide d'une source locale permettant l'étalonnage. Des observations faites en différentes stations, pour la localisation de différentes sources, montrent qu'il existe une similitude étroite entre les enregistrements obtenus.

La question de l'*enregistrement non-directionnel* est mis en discussion.

Mr. Whipple asks how many such stations would be necessary to give a statistical figure for the distribution of atmospherics over the world.

Le Président déclare que cela dépend principalement de la longueur d'onde employée, mais si, comme cela est le cas pour les observations faites en France, on choisit une longueur d'onde de 10.000 m., il convient de prendre une distance de 2.000 km. entre les stations.

Le *Dr. Lugeon* est d'accord sur l'utilité générale des méthodes que vient de résumer le Commandant Bureau et il ajoute que la comparaison des courbes d'enregistrements permet de tirer des renseignements sur la portée des parasites ce qui est important, tant au point de vue commercial que scientifique. Ainsi, M. Lugeon a trouvé pour deux enregistreurs identiques à Zurich et au Sahara, comme en Pologne et à Bear-Island (Cercle Polaire), de grandes différences dans l'aspect des courbes, ce qui démontrait que les appareils étaient sollicités par des foyers différents dont la portée, par conséquent, était souvent moindre qu'au moins la moitié de la distance de 2500 kilomètres qui sépare les récepteurs (1). M. Lugeon suggère une « année internationale d'enregistrements de parasites atmosphériques » où l'on placerait dans chaque continent un ou plusieurs appareils enregistreurs d'un type identique, de manière à obtenir des renseignements mondiaux sur la portée, au moins pour la fréquence de 27 kc/sec. Il faut noter que la portée varie considérablement entre le jour et la nuit. Il est donc nécessaire de comparer les courbes dans des conditions semblables de lumière ou d'obscurité.

Prof. Wagner points out that as different results are obtained according to the arbitrary setting of the receivers that it seems difficult to compare results obtained at two different stations.

Le *Dr. Lugeon* décrit un type de goniographe à amplificateur unique dispensant du réglage toujours difficile de deux amplificateurs identiques. Il consiste en deux grands cadres de 60 m. de hauteur, branchés alternativement à l'amplificateur par un système de soupape travaillant en haute fréquence, hachurant les parasites sans leur faire perdre leurs propriétés. Une même soupape de sortie, synchronisée avec celle d'entrée, conduit le courant induit dans les deux aériens, à deux cadres d'un logomètre solidaires d'un même axe portant une aiguille, laquelle donne directement l'azimut d'un foyer de parasites, à la manière d'un compas (¹). Cet appareil très compliqué ne saurait être recommandé, à cause de son prix élevé et de sa stabilité délicate. Il a fonctionné pendant une année à Jablonna près de Varsovie.

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(1) *C. R. Paris*, t. 191, p. 525, 1929; t. 198, p. 1712, 1934 et *Archives-Genève*, vol. 12, 1930.

Le Président pense qu'à cause du fait que cette forme d'enregistrement peut donner lieu à de nombreuses applications, il conviendrait d'établir une spécification plus précise des appareils.

Mr. Watson-Watt deals with the difficulty of this view of the fact that the more refined forms of apparatus, for instance the Cathode-Ray Tube, shows that a single atmospheric, according to older definitions, actually consists of many peaks of energy; in this case it becomes difficult to define what is meant by a single atmospheric as recorded by different instruments.

Le Président pense qu'un chiffre arbitraire suffit et que tout modèle d'appareil enregistre une grandeur proportionnelle à l'energie reçue.

Mr. Whipple asks whether a calibration in terms of received atmospheric energy is not in this case desirable.

Le Président insiste à nouveau sur la valeur des résultats purement comparatifs, mais il ajoute que l'étalonnage du système enregistreur en fonction de l'énergie reçue est une possibilité qu'il estime désirable.

Mr. Watson-Watt asks whether conclusion to be drawn from the close similarity of the curves obtained by Commandant Bureau, is that the form of the atmospherics recorded are alike, and thus the recorded results are always proportional to the received energy.

Le Président signale que pour obtenir des couches semblables en des points éloignés il est nécessaire de régler les récepteurs sur la même bande d'ondes. Il montre un certain nombre de courbes et signale l'intérêt de l'enregistrement multiple de plusieurs ondes en une station. Il signale aussi que la similitude de courbes obtenues à plusieurs milliers de kilomètres de distance est une indication favorable pour la valeur du système d'enregistrement et pour la comparabilité des résultats qu'ils fournissent.

Mr. Watson-Watt asks if it is desirable to separate the discussion on the two types of recording.

Le Président suggère en réponse qu'il n'est pas désirable de marquer une préférence pour l'un ou l'autre type d'appareil; il est cependant important de spécifier, en connection avec tout appareil utilisé, les conditions d'emploi.

Le Président ouvre la discussion sur l'*enregistrement directif*. Il souligne brièvement l'extension prise, en particulier en France, par l'enregistreur à secteur étroit, aux dépens de l'ancien système à cadre tournant unique. Il a modifié l'enregistreur à secteur étroit surtout dans les circuits où s'opposent les courants et dans le dispositif d'enregistrement; il a utilisé une lampe à néon qui donne une impression photographique sur un papier exploré en spirale suivant le mode employé dans les disques de phonographe. L'appareil inscrit automatiquement des cercles horaires; inscrit également sur les diagrammes les directions repères ainsi que la durée de la nuit.

(¹) Voir : Iurtzman et Starnecki, Le radiogoniographe Lugeon enregistreur de la direction moyenne des parasites atmosphériques : *Przegląd Radiotechniczny*, Rok XIV, z. 24, 15-XII-1934, Warszawa.

Le *Dr. Lugeon* décrit un type d'enregistreur qu'il a perfectionné; il consiste en deux larges cadres dont les sorties sont branchées automatiquement à l'entrée d'un amplificateur à connexions synchronisées. Cet appareil a été abandonné à cause de son prix élevé.

Mr. Watson-Watt states that the narrow sector recorder at Slough has recently been modified in order to provide a thunderstorm index figure for the ionosphere correlation work; for this purpose, a cardioid receptive diagram is used in order to give better time sampling; he is however prepared to revert to narrow sector recording if the Sub-Commission feels desirable for the comparison of results.

Le Président croit qu'il serait désirable que l'on revienne à cette méthode en Angleterre, si cela est possible.

Le *Dr. Lugeon* considérant les comparaisons internationales, estime qu'il est essentiel de fixer des longueurs d'ondes; des chercheurs français ont choisi 30 kc/sec. car en-dessous de cette fréquence les conditions de la propagation conviennent moins bien, et au-dessus de cette fréquence, l'interférence des postes est gênante.

Le Président, en réponse à M. Watson-Watt, déclare qu'il a pu lutter efficacement contre les brouillages sur des ondes d'environ 30 kc/sec., avec une bande passante d'environ 4 kc/sec.

Mr. Watson-Watt reviewing the series of frequencies suggested by the American National Committee, says that 12 kc/sec. is useful for the high atmospheric-signal ratio and in view of the fact that much data on the more academic side of atmospherics investigations is available, 60 kc/sec. is desirable inasmuch as the propagation law is convenient, and in being at the mid-band of the Transoceanic commercial channels; 300-1500 kc/sec. covers the broadcast band, 1500-7500 kc/sec., marine work, whilst 7500-20.000 kc/sec. includes most long distance telegraphy and telephony communications. He suggests in addition, the inclusion of a frequency of 24 kc/sec., as he has been led to adopt this from the standpoint of minimum signal interference; he stress the fact that, in view of interference of this form, it is impossible rigidly to adhere to given frequencies. He adds that whilst the utility of the suggested observational frequencies of 4.000 and 15.000 kc/sec. is evident, he does not consider it advisable to include them in the series at this stage of investigation.

Le Président mentionne qu'il a abandonné la fréquence de 50 kc/sec. pour celle de 30 kc/sec. pour avoir de meilleures conditions de propagation et il suggére l'addition de cette fréquence à la liste. Il regrette aussi l'exclusion de 90 kc/s. qui a fourni des renseignements précieux sur les orages pas trop éloignés.

Après discussion, la proposition suivante est adoptée :

« Que la série de fréquences 12, 24 à 27, 60, 90, 300, 1.500, 7.500 et 20.000 kc/sec. soit adoptée pour l'enregistrement des atmosphériques ».

Le *Dr. Lugeon* fait remarquer qu'une bande intéressante, celle des atmosphériques à basse fréquence, du genre de celles reçues par un système récepteur apériodique, mériterait d'être comprise dans cette liste.

Une étude du Dr. Lugeon relative à ce sujet est lue et traduite en anglais avec la collaboration de M. Watson-Watt.

Mr. Whipple asks whether it is possible to develop means for giving information on the amount of electrical disturbance in different parts of the world at all times, in order to give correlation data day by day; this may be accomplished by means of a number of recording stations reporting to central headquarters. He submits the following resolution for consideration by the Sub-Commission :

« The Sub-Commission recommends that a permanent Sub-Commission be appointed to organize the recording of atmospherics in such a way that the rate of generation of electrical disturbance in all regions of the globe at all times may be determined ».

This recommendation is endorsed by *Dr Schonland.*

Le Président déclare que les résultats actuels donnent une idée approximative des régions de perturbation maximum, et il fait remarquer la difficulté de fournir dans un avenir immédiat, les informations demandées dans la proposition.

Mr. Watson-Watt suggests that the Cathode-Ray Direction-Finding results would give information regarding the received field-strenght of atmospherics, and also their point of origin; this is not generally the case with other methods, as the source cannot be inferred from the knowledge of the received field; a delay in the analysis of Cathode-Ray Direction-Finding results is, of course, inevitable. In view however of the wide range of the proposition, he suggests that whilst supporting the proposition in its ideals he would prefer to indicate that the object is not one which can be attained in the near future. He therefore moves the adoption of the proposition in the following amended form :

« The Sub-Commission recommends that a permanent Sub-Commission be appointed to organize the recording of atmospherics in such a way that the rate of generation of electrical disturbance in all regions of the globe at all times may ultimately be determined ».

La proposition ainsi amendée est adoptée.

La séance est levée à 16.45 heures.

Sous-Commission 4. — Enregistrement de la direction des Atmosphériques

Sub-Commission 4. — Directional Recording of Atmospherics

Séance du mardi 18 septembre. — Meeting held on Tuesday, September 18th.

1. La séance est ouverte à 15 heures, sous la présidence de M. R. A. WATSON-WATT, assisté de M. F. E. Lutkin comme rapporteur.

2. Assistent à la séance : MM. le Commandant R. Bureau, Dr. J. Lugeon, Prof. Dr. H. Norinder, Prof. Dr. W. Wagner.

3. La Sous-Commission a été instituée à la Séance Plénière de la Commission III du 18 septembre, pour discuter et établir un rapport sur l'enregistrement de la direction des atmosphériques.

4. *The President* opens the meeting with a brief résumé of the stations now equipped with cathode-ray direction-finders in Britain, Australia, Canada and U. S. A., and states that two more would probably be added shortly at Florida and Puerto-Rico respectively. He feels it is important to add Swedish and Moroccan stations.

Prof. Wagner thinks that the can also equip a cathode-ray direction-finding station if specifications could be supplied to assist in the construction of the apparatus.

5. Il s'en suit une discussion au sujet des différents types d'appareils pour l'enregistrement de la direction des atmosphériques à l'arrivée et sur leurs qualités pour leurs différentes applications au point de vue météorologique, géophysique, etc. Au point de vue météorologique, le type d'enregistreur à cadre à secteur étroit est considéré comme celui qui convient le mieux, alors que le goniomètre à rayon cathodique donne des indications plus détaillées, requises par ceux qui s'occupent du côté physique de la question.

6. Après discussion on adopte les résolutions à soumettre à l'approbation de la Commission III

Résolutions.

1. The Sub-Commission having considered the results already obtained in daily recording by the narrow-sector method, considers that the organization of an extended network, of open mesh, of narrow-sector radiogoniometers is at the present moment one of the most rapid means for improving our knowledge of the principal sources of atmospherics and to allow a more profound study of the relations between these sources and meteorological phenomena.

The Sub-Commission recommends that :

1) Recording should be continued in the stations where it is now being carried out and should be resumed in those in which it has been suspended.
2) Whenever circumstances permit new recording wave being about 27 kc/sec.
3) The exchange of results should be organised either by postal or by radiotelegraphic means.

2. The Sub-Commission is of opinion that the observations now being made by the aid of cathode-ray direction-finders are of importance to studies on the nature and origin of atmospherics, and that observations of this character should be carried out by an extended network of open mesh. In particular it is of opinion that installations in Germany and Sweden, and in Africa and North-America would be of especial value. It is further of opinion that some strictly simultaneous observations should, whenever possible, be arranged.

COMMISSION IV. — LIAISONS AVEC LES OPÉRATEURS, LES PRATICIENS, LES AMATEURS ET LES SCIENCES CONNEXES

COMMISSION IV — COOPERATION WITH OPERATORS, PRACTITIONERS, AMATEURS, AND CONNECTED SCIENCES

INTRODUCTION

L'absence du Prof. Kennelly, Président de la Commission IV, n'a pas permis à cette Commission de siéger normalement pour examiner les divers sujets proposés à son activité (¹).

The absence of Prof. Kennelly, President of Commission IV, did not allow this Commission to work normally nor to discuss the various subjects submitted to its activity (¹).

Séance plénière du mercredi 19 septembre.

Full Meeting held on Wednesday, September 19th.

La séance est ouverte sous la présidence du Dr. B. van der Pol, assisté de M. J. F. Herd comme rapporteur.

The Chairman. — I have been asked to open this short session of Commission IV. As you know, Commission IV did not have any formal meetings, but a resolution has been prepared to be finally submitted to the full session.

The Chairman reads the resolution (²).

Prof. Appleton. — I should very much like to second that proposal, because it has seemed to me very desirable to have documentary records of Ursigrams. It is true that the information is broadcast from America, but it is my experience as a worker in this field that it is only necessary to have weekly or fortnightly

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(¹) Voir p. 14.

(¹) See p. 14. (²) See p. 118.

accounts of these geophysical cosmic data. For example, as long as such records are sent to me, I do not find it necessary to listen each day for the signals from America. Perhaps I might not be able to receive them if I tried. Therefore I am very glad indeed that there has been put forward this proposal to collect all data of similar character and issue it in a single document.

The Chairman. — Has anybody else any remark to make ?

Mr. Eckersley. — There is one point about the radio transmissions : anybody can get them, will everybody have the documents ?

Prof. Appleton. — The documents should be circulated in addition the to wireless transmissions.

The Chairman — It is meant that the Ursigrams shall be transmitted by radio in the usual way, but it is in addition that these Ursigrams should be sent to Dr. Goldschmidt who will transmit them on paper to the various National Committees.

Mr. Jensen. — Dr. Dellinger has proposed certain changes in the code for the Ursigrams. He has already left, but he has talked to Prof. Mesny about it, I think.

Prof. Appleton. — Dr. Dellinger handed me this document and asked me to look through it. It seemed to me very sound and most desirable that the suggested changes should be made. I do not know whether the meeting would like to adopt a document it has not seen. Two members at least have seen it and think they are changes which should be adopted.

Prof. Wagner. — Until now those Ursigrams should be sent by letter directly from America and I would like to know whether this shall be stopped if we move the proposed resolution.

The Chairman. — I was not in touch with the details of this question, so I cannot answer your question. Perhaps Prof. Appleton could give further information. Prof. Wagner asks whether, when this will be adopted, the direct mailling by the Science Service of the Ursigrams will be discontinued.

Prof. Appleton. — No. They are two entirely different matters.

The Chairman. — I suggest we leave the details of the small changes of the code to Dr. Dellinger and Prof. Appleton. We all think the code will be improved if these two gentlemen tackle the problem. (*Agreed.*)

Any further suggestions ? If not, then I think we close this session.

COMMISSION V. — RADIOPHYSIQUE
COMMISSION V. — RADIOPHYSICS

INTRODUCTION

Les documents ci-après intéressants les travaux de la Commission V, furent distribués en vue de l'Assemblée Générale (¹).

The following papers interesting the works of Commission V, were circulated in view of the General Assembly (¹) :

N° 6. — The Nature of the Solar Radiation and Composition of High Atmosphere, by S. Chapman.

N° 12. — The Symbolic Calculus with some Applications to Radiotelegraphy, by B. van der Pol.

(¹) Voir résumés p. 120.

(¹) See abstracts p. 120.

Nº 21. — Sur l'Etude en Laboratoire des Propriétés Diélectriques des Gaz Ionisés, par C. Gutton.
Nº 22. — Die Erzeugung von Wellen unterhalb 1 m. Länge, von K. W. Wagner und H. E. Hollmann.
Nº 27. — Report of Radio Research in Japan, by the National Japanese Committee.
Nº 38. — Laboratory Investigations of the Dielectric Constant of Ionised Air, by Prof. E. V. Appleton.
Nº 40. — Transmission and Reception of Nine-Centimetre Waves, by G. R. Kilgore.
Nº 41. — An Electron Oscillator with Plane Electrodes, by B. J. Thomson and P. D. Zottu.
Nº 44. — Exposé des Recherches récentes sur les Oscillations non linéaires, par L. Mandelstam, N. Papalexi, A. Andronow, S. Chaikin et A. Witt.
Nº 47. — The Non-Linear Theory of Electric Oscillations, by B. van der Pol.
Nº 63. — Application de la Mécanique non linéaire à quelques problèmes de la radiotechnique moderne, par le Prof. Dr. N. Kryloff et le Dr. N. Bogoliùboff.
Nº 64. — A Critical Résumé upon High-Frequency Bridge Networks, by T. Iorwerth Jones

Séance d'ouverture du mercredi 12 septembre.

Opening Meeting held on Wednesday, September 12th.

La séance est ouverte sous la présidence du Dr. B. van der Pol, Président de la Commission V.

The President. — I may remind that in Copenhagen, we elected a Vice-President and Reporter for Commission V and the Vice-President was Prof. Mesny and Reporter M. Le Corbeiller. In Copenhagen, it was also decided that some papers should be written as a basis for a discussion in Commission V. Slight changes have occured in the orders of these papers, and I want now to communicate to you these changes.

First it was decided that a joint paper by Prof. Gutton and Prof. Appleton would be written on the dielectric constant of an ionized gas under high frequency oscillations. It was found more praticable if Prof. Appleton and Prof. Gutton wrote their contribution separately, so we have two contributions on the same subject, one written by Prof. Appleton, and the other written by Prof. Gutton.

Further, it was decided in Copenhagen that a joint paper on the constitution of the higher atmosphere and solar radiation was going to be written by Prof. Chapman and Father Lejay. The latter is now in China so that in the present circumstances it was difficult to prepare this report, so we have available only a very interesting report by Prof. Chapman. Further, it was agreed upon in Copenhagen that a joint paper should be written on the symbolic calculus by Dr. Wagner and myself. We have corresponded on how we should divide the subject, and it was rather difficult to divide it in two parts, so Dr. Wagner suggested that I should write the note, which I have done.

In Copenhagen we also found Dr. Wagner prepared to write a report on the generation of ultra-short waves. Dr. Wagner has found his collaborator, Dr. Hollmann, ready to co-operate with him, and so the paper which is going to be presented is from them both. These papers will be distributed to the members of the different sub-commissions, which we will now form.

Finally, I have asked some Russian scientists to prepare a report on the subject which has been much developed lately in U. R. S. S. It is the theory of the generation of non-linear oscillations. I thought it would be of interest to discuss these questions here in Commission V, because these theories form a fearly fundamental subject of the whole of radio telegraphy, and I thought that it would be wise to ask these

Russian physicists to contribute a summary of work because so much work has lately been done over there. I understand, for instance, that a group of ten physicists, a similar group of mathematicians and a similar group of technicians are working in different laboratories in one organisation on the theory of non-linear oscillations. Some of the work has already been published in Russian papers but no connected account is available of this very interesting work. A report has been written by Prof. Mandelstamm and Prof. Papalexi in co-operation with Andronow, Chaikin and Witt, and another report I have received from Prof. Kryloff and Bogoliùboff have been reproduced. They are ready for distribution to the members of the sub-commission which will deal with the subject.

We have next to divide the work into sub-commissions.

Sub-Commission 1. — *Physics of the Upper Atmosphere.*

President : Prof. Mesny. *Members* : Prof. E. V. Appleton, Prof. Chapman, Dr. Eccles, M. Eckersley, Prof. Elias, M. Heising, Prof. C. Manneback, Lt.-Col. Marino, Dr. B. van der Pol, Dr. W. Wagner, Prof. Yagi.

Papers under this Sub-Commission : N° 6, 21 and 38.

Sub-Commission 2. — *Generation of Ultra-Short Waves.*

President : Dr. W. Wagner. *Members* : MM. Barton, Heising, Dr. Mac Petrie, Comm. Matteini, Prof. Mesny, Dr. Smith-Rose, Prof. Yagi. Papers under this sub-commission : N° 22, 40 and 41.

Sub-Commission 3. — *Theory of Oscillations.*

This sub-commission covers the subjects of

1. — the Symbolic Calculus, and
2. — the Reports from the U.R.S.S.(¹), one from myself (¹) and also a contribution from Prof. Appleton who is kind to offer us a short account of some recent experiments under his direction.

President : Dr. B. van der Pol. *Members* : Prof. Appleton, Dr. Dellinger, M. Eckersley, Prof. Elias, M. Espenchied, M. Koga, M. Kirke, M. Le Corbeiller, Prof. Manneback, Prof. Mesny, Dr. Mary Taylor, Prof. Turner, Prof. Yagi, Dr. Wagner.

Papers under this sub-commission : N° 12, 44, 47, 63 and contribution by Prof. Appleton.

It was decided in the course of this morning that a sub-commission under the chairmanship of M. Eckersley which was formed by Commission II should be considered also to be a sub-commission of Commission V. This sub-commission is going to deal with the Theory of the Propagation of Waves through the Higher Atmosphere, and I would like to ask M. Eckersley to give us the names of the members of that sub-commission.

Constitution of joint sub-commission :

President : Mr. Eckersley. Members: Prof. Dr. Jhr. Elias, Prof. C. Mannebach, Namba, Dr. van der Pol, Prof. Dr. Wagner.

I hear that Mr. Watson-Watt is going to provide our three sub-commissions with a reporter, so that I think within a short time we can start our work.

I suggest that the proper thing to do would be to start work straight away, because the programme is rather big, so that perhaps I may suggest a day for a meeting of the sub-commissions.

On décide que la sous-commission 1 de la Commission V se réunira cette après-midi de 15.30 heures à 17.30 heures ; la sous-commission 2 à 14.30 heures vendredi 14 septembre, et la sous-commission 3 samedi 15 septembre à 9.45 heures.

(¹) Document n° 44, p. 151 and n° 63, p. 193.

(¹) Document n° 47, p. 165.

Séance de clôture du mercredi 19 septembre.

Final Meeting held on Wednesday, September 19th.

La séance est ouverte sous la présidence du Dr. B. van der Pol.

The President. — We are now having the closing session of Commission V. In our last full session of Commission V, some resolutions have already been adopted, but as the work of the sub-commissions was not finished then, some further resolutions have been given to me to be adopted in this full session. First, as you remember, a sub-commission was appointed under the presidency of Mr. Eckersley, and I would like Mr. Eckersley to give a résumé of the work done.

Mr. Eckersley. — Two sessions of the joint committee of Commissions II and V were held (¹). A formal resolution was adopted concerning further investigation of the theory of propagation and absorption of waves in the atmosphere (²). Papers were read by Prof. Elias and Prof. Manneback on the transmission of waves, and on relations between waves and geometrical optics. Further discussions on the subjects came out. The chief points brought out were the relation between the ray theory and the wave theory, and that formed preparation to the work it is suggested to be carried out by Prof. Manneback and myself on the same subject for the next meeting of the U.R.S.I.

The President. — Any comments ? If not, I want to thank M. Eckersley most warmly for the work he has done in his sub-commission. The work was of a rather theoretical nature, but, as in so many cases, I think the theory can help us considerably to understand those complicated phenomena which happen when waves travel in a region whose constants vary in space.

Gentlemen, I think the resolutions have been distributed in your pigeon-holes, and to make sure that you all agree to them (some have been already adopted) I would like to go through them in a rapid way.

Resolution 1 (¹) is already adopted at the last session. I hear that Prof. Wagner and Prof. Mesny are willing to prepare the report.

Resolution 2 (¹) was discussed, but no one has yet been found to make the report. I would suggest to you to ask the two following gentlemen to prepare a report : Dr. Dellinger and Mr. Eckersley. It is of course understood that they are quite free if they find it of value to ask further gentlemen to assist them. (No remark).

Resolution 3 (¹) is already adopted, and MM. Llewellyn, Moullin and myself will report on the subject.

Resolution 4 (¹). This resolution runs as follows : (The President reads resolution 4, which is adopted; Dr. van der Pol will report on the subject).

Resolution 5 (¹) is also adopted and MM. Eckersley and Prof. Manneback will report.

This finishes the work of Commission V, but I won't close this session without having thanked more heartily Prof. Mesny and Prof. Wagner for the important work which was done in the sub-commissions under their direction. Both sub-commissions had a very hard task because the questions considered there do not belong to the simplest ones of radio, they are very often complicated, and it may perhaps be considered as an indication of the modesty of all of us that we have the feeling that we did not quite get the bottom of many problems involved in the questions discussed in those sub-commissions.

I wish to thank also Mr. Picault and Mr. Kirke for the work they did in preparing the scheme for the international co-operation for finding

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(¹) See accounts p. 56.
(²) See p. 119.

(¹) See p. 119.

out more about the interaction of radio waves in the ionosphere. I hope that also this work will be a success, and that important progress can be reported after two or three years. I was myself present mostly during all the work of these sub-committees, and I must thank the Presidents again most heartily for their interesting and difficult work.

And finally, I wish also to say a word of thanks to M. Herd. I do not think that Commission V would have accomplished its work in the time put at its disposal without the assistance of M. Herd in finding times for our sessions so that we did not interfere too much with the work of the other sub-commissions and vice-versa.

And in conclusion a word of thanks to the reporters, who have been so very active in helping us through the work. It is easy to be President and Vice-President, but the work falls a great deal on the reporters, who have to work during and after the session.

If there is no further matter to be discussed, or any further suggestions to be made in connection with the work of Commission V, I have to thank you all very much for your presence, and we hope to come together again after two or three years.

Sous-Commission 1. — Physique de la haute Atmosphère

Sub-Commission 1. — Physics of the Upper Atmosphere

Séance du mercredi 12 septembre. — Meeting held on Wednesday, September 12th.

1. — La séance est ouverte à 15.30 heures, sous la présidence du Prof. R. Mesny, Président de la Sous-Commission, assisté du Dr. Mary Taylor comme rapporteur.

2. — Assistent à la séance : MM. le Prof. E. V. Appleton, P. Baudoux, T. L. Eckersley, le Prof. Jhr. G. Elias, l'Ing. T. Gorio, le Prof. F. E. W. Hackett, le Dr. B. la Cour, Dr. J. S. Mac Petrie, le Prof. Dr. H. Norinder, le Dr. B. van der Pol, le Prof. Dr. K. W. Wagner, le Dr. F. W. G. White et le Prof. H. Yagi.

3. — *Le Président* déclare que par suite de l'absence du Prof. Chapman, la discussion de son étude (¹) est remise à une séance ultérieure.

4. — *Discussion sur la constante diélectrique d'un milieu ionisé* (Documents n° 21 et 38).

Le Président prie le Prof. Appleton de faire l'exposé de son étude (²).

Prof. Appleton states that laboratory investigations on the dielectric constants K of the ionised air has been initiated by Dr. van der Pol in the Cavendish Laboratory, Cambridge, in 1919. He found that K could assume values smaller than 1. In 1927, H. Gutton and G. Clement found that K could be smaller than 1 and also discovered a phenomenon suggesting the presence of characteristic frequency in the gas.

Prof. Appleton considers that these experimental observations are correct but their interpretation are different from that given by Gutton and Clement.

He inclines to the explanation given by Pedersen and Rybner and the purpose of the work described in document 38 was to attempt to settle the point experimentally. He uses the probe method of Langmuir and Mott-Smith to measure N and the results tabulated show agreement with Pedersen's explanation. Another possible explanation is that of plasmoidal oscillations given by Langmuir and Tonks, but Prof. Appleton is doubtful about this as the oscillations arise owing to presence of the boundary.

(¹) Document n° 6.

(²) Document n° 38, p. 148.

Le Président donne un aperçu des principes de l'étude de Gutton (¹). Les phénomènes de résonance sont dus à ce que la masse gazeuse est limitée ; les charges qui s'accumulent à ses limites donnent lieu à des forces élastiques. La haute atmosphère peut être considérée comme limitée approximativement par deux plans horizontaux et les nuages d'électrons qui doivent s'y trouver constituent également des masses limitées ; on doit donc s'attendre à y voir se produire des phénomènes analogues à ceux que l'on constate dans les tubes ayant servi aux expériences.

Prof. Appleton remarks that the Gutton effect is very marked in laboratory experiments but he is not aware of its having been observed in wireless phenomena. The crucial question seems to be : is there any reason why the dielectric constant of an ionised medium should *not* assume negative values ?

Prof. Elias remarks that the ratio of volume to surface in the upper atmosphere is very large, so that the boundary effect would be small.

Le *Prof. Manneback* demande si les phénomènes ont été mesurés dans des tubes de dimensions différentes, ce qui résoudrait la question de savoir si c'est un effet de surface ou non.

Prof. Appleton states that different ratios $\frac{C_2}{C_3}$ have been used but not small and large tubes.

Le *Prof. Manneback* suggère de faire un contrôle expérimental de l'effet du volume : en faisant varier le rapport de ce dernier à la surface. Les deux théories (*a*)du Prof. Pedersen et (*b*) de l'effet limité, peuvent, en réalité, être une seule et même théorie. Les oscillations plasmoïdales sont des ondes *stationnaires* données par une valeur négative de K ; les phénomènes optiques sont causés par des ondes *progressives* qui exigent une valeur positive de K.

Le *Prof. Wagner* dit que le physicien ne voit aucune objection à l'existence de valeurs négatives de K ; c'est simplement une extension de la définition, la même idée se présente dans les problèmes de la propagation des ondes le long de conducteurs, où, dans certaines conditions, la capacité et l'inductance deviennent complexes.

Dr. van der Pol agrees with Prof. Wagner that negative values of K are merely a matter of definition. K is a function of frequency and may be either positive or negative. Plasmoidal oscillations occur when stationary waves are present i. e. the phase velocity is infinite (all parts are cophasal) or the group velocity is zero. The change of sign of K is the physical expression of the mathematical transition of the partial differential equation of the oscillations from the hyperbolic to the elliptic type ; this is a *real* distinction.

Dr. van der Pol further enquires the reason for writing equation (1) in document 38 in the form given. What has happened to the Lorentz-Hartree polarization term formerly inserted by Prof. Appleton ?

Prof. Appleton gives a short résumé of the history of the adoption and subsequent omission of this term ; theoretical arguments by Tonks, Norton and Darwin and laboratory experiments in which it was not found were evidence against the validity of its presence.

Prof. Elias remarks that the numerical value 1/3 adopted for the term depends on the shape of the cavity assumed round the electron whose movement gives the fundamental equations of the theory.

Mr. T. L. Eckersley remarks that three theories are under consideration.

(¹) Document n° 21, p. 140.

1. — That of natural oscillations of the ionised medium.
2. — That of no natural oscillations of the ionised medium.
3. — That of no natural oscillations in Tonks' arrangement.

There is really no difference between nº 3 and the ordinary theory of an ionised medium; zero group velocity and presence of stationary oscillations of the medium at the critical frequency.

Prof. Appleton remarks that the theory of Langmuir and Tonks does not apply to a discharge tube, in which there is a sheath of positive ions and which is effectively equivalent to a diode. The varying concentration in the sheath gives rise to electric forces there. Unpublished laboratory experiments have shown that the effects of Gutton and of Langmuir and Tonks are not absolutely identical.

Mr. T. L. Eckersley points out that the sheath is an appreciable fraction of the whole volume of the discharge tube.

Dr. van der Pol recalls a remark of Lorentz to the effect that inhomogeneity of the medium might cause an apparent increase of K. This is fully worked out in his thesis of 1920. In the case of a thin striated dielectric, the value of K given by measurements taken externally is always *greater* than the smallest actually occuring *within* the medium.

Prof. Elias remarks that the influence of the mean free molecular paths is not the same in laboratory experiments and in the ionosphere.

5. — *Discussion sur le coefficient de recombinaison de la haute atmosphère.*

Le Président prie le Prof. Elias d'exposer son étude sur le coefficient de recombinaison de la haute atmosphère.

Prof. Elias says that the idea is to measure the time interval between sunrise at the height of the layer and the time of formation of the layer. The corresponding interval at sunset can also be observed. It is found to be about 2 hrs. in both cases and is smaller than had been expected. The coefficient of recombination α was found in this way to be of the order of 10^{-10}. If this coefficient were proportional to density, in accordance with Langevin's experiments, a lower value might be expected. Later experiments give indeed a larger value of α at lower densities. On the other hand the breath of spectral lines in the aurora seems to show that the temperature of the upper atmosphere may be much higher than that expected, a circumstance which would cause a higher density than at lower temperature.

Prof. Elias suggests that laboratory experiments may be made on the variation of α with the two quantities; temperature and density of the gaseous medium.

Mr. T. L. Eckersley points out that his experiments and Prof. Chapman's calculations agree in giving a value of α for F-region of 1.2×10^{-10}.

Prof. Elias remarks that at the earth's surface α varies as 10^{-6}; this ratio of 10^4 between the values of α at the surface and in F-region necessitates a large variation of temperature, if α is proportional to density.

Mr. T. L. Eckersley suggest that the discussion may be adjourned until Prof. Chapman could be present as he has developed the theory of atmospheric ionization and recombination.

6. — *Discussion sur l'absorption des ondes électromagnétiques dans un milieu magnéto-ionique* (expériences de laboratoire).

Le Président invite M. Gorio a présenter une étude du Prof. Todesco sur des observations expérimentales dans un milieu d'ionisation magnéto-active.

The paper is read by *Prof. Appleton.* Prof. Todesco has already demonstrated the existence of selective absorption in a ionised medium in the presence of an external magnetic field. The electron orbits are then shown to be circles. It

is however now found that, if the effect of space charge in the filament-anode space are considered, the orbits are cardioides and Langmuir's space charge law gives pseudo-cardioides. Prof. Todesco has now confirmed this experimentally, using 18 cm. waves.

7. — La séance est levée à 17.30 heures.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

1. — La séance est ouverte à 11.30 heures, sous la présidence du Prof. R. Mesny, assisté du Dr. Mary Taylor comme rapporteur.

2. — Assistent à la séance : MM. le Prof. S. Chapman, le Prof. Dr. Jhr. Elias, J. A. Ratcliffe, le Dr. B. van der Pol, le Prof. H. Yagi.

3. — *Le Président* ouvre la séance en invitant le Prof. Chapman à donner un aperçu de son étude (¹).

4. — *Discussion sur la Composition et la Température de la Haute-atmosphère.*

Prof. Chapman gives an account of his paper.

Mr. Ratcliffe remarks that measurements he is making on absorption give a value of 2×10^3 for the collision frequency at 250 km. height, and says that this is on agreement with Prof. Pedersen's value. He asks how this value would compare with values to be deduced from Prof. Chapman's theory.

Prof. Chapman says that he cannot give a definite answer to this question until more calculations have been done; Prof. Pedersen assumes an atmosphere consisting of helium at great heights but lower temperatures than his (Prof. Chapman's) theory gives, so the effects may balance out and approximately the same values be obtained for the collision frequency.

After further discussion of probable diurnal temperature variation, *Dr. van der Pol* suggests that Prof. Chapman should give a complete table of the composition, temperature, pressure and density of the atmosphere as given by his theory.

Prof. Chapman states that calculations are already in progress and would be published in an English scientific journal.

5. — *Discussion sur la constante diélectrique d'un milieu ionisé* (suite) (¹).

Le Président expose avec plus de détails que dans la précédente séance, les idées de M. Gutton; il montre, en particulier, que si l'on considére une onde se propageant dans une couche limitée par deux plans parallèles, le champ électrique, étant perpendiculaire à ces plans (²), les charges induites sur ces plans limites ne peuvent être négligées que si leur distance est grande par rapport à la longueur de l'onde; or, dans une région où la constance diélectrique apparente est voisine de zéro, la longueur d'onde devient très grande et la condition précédente ne peut être satisfaite.

Dans ces conditions, M. Gutton estime qu'il est impossible de considérer le milieu ionisé comme illimité et qu'il est indispensable de tenir compte des charges accumulées sur ses surfaces limites pour étudier la propagation; dans une telle étude, les phénomènes de résonance doivent jouer le principal rôle. En particulier, il est raisonnable d'admettre que la réflexion sous une incidence presque normale doit se produire sur une couche en résonance, comme dans le cas des réflexions optiques utilisées par Rubens pour isoler les rayons restants.

M. Gutton a en outre signalé des expériences de réflexion sur la couche Kennelly-Heaviside qu'il a faites par la méthode des tops, en utilisant des signaux extrêmement amortis produits

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(¹) Document nº 6.

(¹) Voir p. 86.

(²) Voir document nº 21, p. 140.

par une seule étincelle en série dans l'antenne d'émission. Ces signaux n'ont jamais donné lieu à des échos alors que des signaux entretenus émis dans les mêmes conditions en fournissaient. Ces expériences sont encore d'accord avec l'existence d'une résonance (¹).

Dans la discussion qui a suivi, on fait remarquer que dans le cas de réflexions sous des incidences très différentes de 90°, telles que celles qui se produisent dans la pratique des communications, la propagation des ondes dans le milieu ionisé se produit dans des régions où la constante diélectrique apparente est très différente du zéro et où, par conséquent, la longueur d'onde reste petite vis-à-vis de la distance des surfaces limites, le milieu peut alors être considéré comme illimité. Quant au cas de la réflexion normale, il ne paraît pas possible de lui appliquer un raisonnement analogue à celui qui est employé pour une propagation parallèle aux plans limites.

Il serait désirable qu'une étude quantitative de la question soit abordée pour contrôler l'influence de résonances éventuelles.

Prof. Elias remarks that Frl. Szekely (Graz) has also found a natural frequency of an ionised gas but this also depends on the boundaries and the voltage. Prof. Elias says that there is an analogy between rain-clouds at low levels and ion clouds formed by corpuscular radiation at ionospheric levels.

5. — La séance est levée à 12.30 heures.

Sous-Commission 2. — Génération des Ondes ultra-courtes
Sub-Commission 2. — Generation of Ultra Short-Waves

Séance du vendredi 14 septembre. — Meeting held on Friday, September 14th.

La séance est ouverte à 14.45 heures, sous la présidence du Prof. Dr. K. W. Wagner, Président de la Sous-Commission, assisté du Dr. J. S. McPetrie comme rapporteur.

Assistent à la séance : MM. F. S. Barton, Dr. T. Gorio, R. A. Heising, I. Koga, Dr. J. S. McPetrie, Comm. Matteini, Prof. R. Mesny, Dr. B. van der Pol, Prof. H. Yagi.

The President states that in accordance with a resolution passed at the Copenhagen meeting of the U. R. S. I. he had prepared a résumé of the work published on the Production of Waves of less than 1 metre in lenght. The résumé has been translated into English and is available at the meeting.

Dr. van der Pol in opening the discussion on this paper emphasises the difficulties met with in the study of electronic oscillators. He points out that Benham has shown theoretically that a condition of negative resistance over a certain frequency band is possible in a two electrode valve. On this hypothesis an *oscillatory* motion of the individual electrons within the valve is *not* necessary for the production of oscillations. The difficulty in obtaining oscillations with an ordinary diode is in realising a suitable resonant circuit. Dr. Mc. Petrie has produced electronic oscillations using a cylindrical electrode diode in which the cathode is external to the coaxial anode. This was also fully confirmed in the Eindhoven laboratory.

Dr. Mc. Petrie describes recent experiments made by him with two such diodes having similar dimensions but the operating temperature of the cathode in one valve is high while in the other which is activated it is low. The output is greater in the case of the valve with

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(¹) Document n° 21, p. 140.

the low temperature cathode. This result indicates that in such valves the negative resistance condition responsible for the oscillation is in some way due to the direct transit of electrons from the cathode to anode of the valve and not to a to and fro motion of the electrons about the anode.

Mr. Heising summarises a paper by B. J. Thompson and P. D. Zottu entitled « An Electron Oscillator with Plane Electrodes » (¹) and another by G. R. Kilgore on the « Transmission and Reception of 9 cm. waves ». (²)

The first paper describes how electronic oscillations can readily be produced in a plane electrode triode if a plate which is given a small negative potential is placed near the filament and on the side of it remote from the other electrodes. It was found possible with valves of this design to produce waves of less than 10 cm. wavelength with a grid voltage of only 150. The results of the tests described in the second paper suggest that communication over a clear path 20 miles in length can be obtained in a wavelength of 9 cm. with a total input to the transmitter of 15 watts.

In answer to an inquiry by Dr. van der Pol, *Mr. Heising* states that Llewellyn has found that an electronic space charge within a valve does not essentially prevent electronic oscillations from occuring.

Mr. Barton describes the results of communications between Lympne and St. Inglevert on a wavelength of 18 cm. Much fading has been experienced.

MM. Heising, Mesny, Matteini et le *Prof. Wagner* décrivent des résultats semblables obtenus sur une gamme de longueurs d'ondes de 600 à 50 m.

On convient que les effets de « fading » sont généralement prononcés lorsque les ondes passent à proximité d'une masse d'eau.

La Sous-Commission décide à l'unanimité de mettre les points suivants à l'ordre du jour pour la prochaine Assemblée Générale de l'U. R. S. I.

1. — Continuation de l'étude de la génération des oscillations électroniques aux ultra-hautes fréquences, y compris celles appelées communément oscillations de Pierret.

2. — Etude de la propagation des ondes ultra-courtes en vue des communications à distance ; cette étude comprendra la détermination des effets de l'atmosphère.

Sous-Commission 3. — Théorie des oscillations

Sub-Commission 3. — Theory of Oscillations

Séance du samedi 15 septembre. — Meeting held on Saturday, September 15th.

La séance est ouverte à 10 heures, sous la présidence du Dr. B. van der Pol, Président de la Sous-Commission, assisté de M. F. M. Colebrook comme rapporteur.

Assistent à la séance : MM. le Prof. Appleton, T. L. Eckersley, le Prof. Manneback, le Prof. Mesny, le Dr. Smith-Rose, le Dr. Mary Taylor, Vigoureux.

The President, in opening the session, remarks that the programme can be divided in two subjects :

1. — symbolic calculus,

2. — theory of non-linear oscillations.

The first point to put forward is to discuss which of the two subjects ought to be discussed first.

(¹) Document nº 41, p. 149.

(²) Document nº 40, p. 149.

La majorité des membres est d'accord pour voir discuter en premier lieu la question *du calcul symbolique.*

The President states that at the Copenhagen meeting, it was agreed that he and Dr. Wagner should present a report on this subject at the present meeting of the U. R. S. I. Both physicists corresponded very much, but they saw that collaboration for such a work was rather difficult, and Dr. Wagner asked the Chairman to report individually; paper n° 12 has therefore been prepared by Dr. van der Pol.

Summarizing this work, he declares that Heaviside, more than 40 years ago, had remarked that by substituing to the differential sign d/dt, the algebric sign p, many electro-magnetic problems could be resolved which could only be resolved with difficulty by the ordinary methods of mathematical analysis.

Since then, the works of Bromwich, Carson and Wagner have rigorously established that calculus on a sound basis.

For this calculus, the Chairman prefers the name of « symbolic » instead of « operational ».

Carson's formula gives the « image » function $f\ (p)$, in terms of the « original » $h\ (x)$, whilst the Bromwich's formula gives $h\ (x)$, when $f\ (p)$ is known. Levy demonstrated that both formula are equivalent, and that each of them is the single solution of the other. $h\ (x)$ is called the « original » and $f\ (p)$ the « image ».

The President remarks that the symbolic calculus does not bring the solution to problems which cannot be resolved by ordinary methods of mathematical analysis, but it often brings a great simplification which makes much easier the working out of such questions.

He then shows by several examples how, by passing, before making the calculus, from the « original » to the « image » which often is a simpler function, formulas can easily been established whilst the working out by ordinary methods is very complicated.

Prof. Appleton thanking the President, remarks on the analogy with logarithms. One requires one set of tables to give the image of the original and another set to give the original of the image.

The President replies that he has prepared and used such tables.

Mr. Eckersley asks if symbolic calculus may be applied to linear equations with varying coefficients.

The President answers that this is quite possible and refers to a paper on the question (¹).

Le *Prof. Manneback* demande si l'on peut obtenir par le calcul symbolique des règles générales pour passer d'une équation différentielles à une *équation aux différences finies* et vice-versa.

The President indicates a method capable of giving the required rules.

Mr. Eckersley should like to know if the case of a particular function $h\ (x)$, i. e. a function having a infinite number of discontinuities, has been worked out.

The President says that in the case of a finite number of discontinuities, the problem can be solved.

Le *Prof. Manneback* pense que les conditions que doit remplir la fonction $h\ (x)$ sont de même nature que les conditions de Dirichlet pour le problème de Fourier. Il se demande si la restriction dont avait parlé M. le Président, à savoir que $h\ (x)$ fût nulle pour x négatif est vraiment nécessaire au théorème d'équivalence de Lévy.

The President answers affirmatively and says that the necessity of this restriction has been shown by G. Doetsch. He remarks that the time allowed to the session is over and he hopes to be able to find time to discuss the theory of non-linear oscillations later.

La séance est levée à 11.15 heures.

(¹) *Phil. Mag.*, Dec. 1929.

Séance du lundi 17 septembre. — Meeting held on Monday, September 17th.

La séance est ouverte à 15.30 heures, sous la présidence du Dr. B. van der Pol, assisté de M. Vigoureux comme rapporteur.

The President mentions three papers for consideration, one by himself (¹) and also two by Russian physicists : one by MM. Mandelstam and Papalexi, C. S., and one by MM. Kryloff and Bogolinboff (²) whom, after consultation with the President of the U. R. S. I., he had asked to send him communications on their work, about which very little had been published, except in the Russian language.

The President then proceeds to summarise his own paper. He points out that the mere fact that oscillations can be generated in a triode fed from direct current shows that the system is non-linear.

After giving examples of the differential equations connecting amplitude with time, he stresses e. g. the great difference between linear equations with periodical coefficients, and non-linear equations. such e. g. as correspond to relaxation oscillations. By a beautifully simple experiment with a pendulum, he illustrates the effect of a periodic coefficient, which may cause a large increase in amplitude. Similar results can be obtained electrically, and have been obtained in Russia, by varying periodically the capacity or the inductance of an oscillator. The oscillations build up until a flash-over occurs.

The President further refers to frequency demultiplication, first obtained a. o. by *Prof. I. Koga.* He considers that what is usually called « dragging into step » or « Mitnahme », in the process of the synchronization of two oscillators, should be viewed rather as the suppression of the free oscillation by the forced oscillation; for as the amplitude of the forced oscillation is increased, the swing over the curved parts of the triode characteristic causes an increase of the average resistance, which prevents maintenance of the free oscillation.

The President then asks *Prof. E. V. Appleton* to summarize his recent researches on that particular subject.

Prof. Appleton shows slides illustrating the coming into step, the « silence » period, during which the phase relation of the two oscillations changes, and the going out of step. The magnitude of the forced oscillation necessary to cause automatic synchronization has been measured experimentally and the value was found to be approximately that predicted theoritically.

Prof. I. Koga agrees with the *President* that the ratio of the two frequencies to which frequency demultiplication can be applied is less in the case of sinusoidal than of relaxation oscillations.

Prof. Wagner refers to the well-known method of representing a. c. phenomena by means of rotating vectors, which has been used by *Bab* (¹) for the study of the phenomenon of synchronization. I this way *Bab* also succeeded in explaining very simply the rather intridated phenomena discovered by *Baerwald*, and called : « Seitenband-Mitnahme », where the side-frequency of a modulated wave is synchronized by an impressed oscillation.

The President continuing his exposition of non-linear oscillations, refers to the systems which need an impulse or « kick » to start them, after which they continue to oscillate of themselves; to the « ziehen » effect, and to relaxation oscillations in systems with more degrees of freedom.

He stresses the complete analogy between the electrical cases dealt with, and the many

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(¹) *Proc. Inst. Radio Eng.*, 22, 1051, 1934.

(²) Documents nº 44 and 63, p. 151 and 193.

(¹) *E. N. T.*, vol. 11, 1934, p. 187.

other types of relaxation oscillations so frequent in nature, and gives the example of the human heart, consisting of 3 parts, which can, under certain circumstances, be made to vibrate at different frequencies, the ventricle frequency being 1/2 or 1/3 of the frequency of the other two portions.

After some discussion by *Prof. K. W. Wagner*, *Mr. Baudoux*, *Mr. J. A. Ratcliffe*, *Prof. Manneback* and the *Président* on the terminology of degrees of freedom, the meeting terminates at 17.45; the *President* announces that another meeting will be arranged for the examination of the work of the Russian physicists.

Séance du mardi 18 septembre. — Meeting held on Tuesday, September 18th.

La séance est ouverte à 11 heures, sous la présidence du Dr. B. VAN DER POL, assisté de M. F. M. Colebrook comme rapporteur.

Assistent à la séance : MM. T. L. Eckersley, Prof. Dr. Jhr. Elias, Prof. Fortescue, Prof. F. Hackett, Dr. Mac Petrie, Prof. Manneback, Prof. Mesny, Dr. Mary Taylor, P. Vigoureux, W. Wilson.

La séance a pour objet la discussion des *équations différentielles non-linéaires*.

The President opens the proceedings by giving a brief outline of the present state of knowledge of oscillations defined by non-linear differential equations, as recorded in papers 44 (¹), 47 (²), 63 (³). He states that there are no known methods of exact solution and describes the nature of the three principal methods of approximate solution (the method of sine waves with a slow variation of amplitude, of expansion in a power series of a small parameter, and the graphical representation of integral curves). With regard to the second of these, he points out that there is very little known about the radius of convergence of the power series. He states that a group of workers in Russia (Mandelstam, Papalexi, etc) has investigated various types of non-linear oscillation, including cases of parametric oscillation (oscillation involving periodic variations of parameter) and has supplemented their theoretical work by experiment.

DISCUSSION.

Prof. Elias asks whether Hegeners experimental work of ten years ago is explained by the Russian theoretical work.

The President replies that he thinks it is a type of parametric oscillation and that such oscillations are discussed in the Russian contributions. He further mentions that his fundamental equation for non-linear triode oscillators can be transformed to one representing variable restoring force, but that the corresponding « pendulum » solution in terms of elliptic integrals is not applicable as the transformed oscillator equation contained a constant damping term.

Mr. Colebrook emphasises the great practical importance of the study of non-linear differential equations, stating that our knowledge of a wide field of radio technique is dependent on this. It seems desirable that other countries should follow the example of Russia in setting up a specific research group for this subject. While the work described in papers 44, 47 and 63 is a valuable contribution, much more remains to be done, since modern technique requires a very much higher degree of accuracy of solution, particularly in regard to frequency, than seems likely to be obtainable by these methods. In triode oscillators the parametric variation due to the dependance of interelectrode capacitance on frequency seems to be of considerable practical significance.

The desirable objective is a « transparent » analytical solution in which the significance of

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(¹) See p. 151.
(²) See p. 165.
(³) See p. 193.

the various individual parameters is made clear. It may be found that a new analytical technique would have to be evolved before this could be achieved.

The President, in comment on this, points out that the approximate methods are valuable in giving an explanation of the general march of the phenomena. There are, however, possibilities of higher accuracy in the methods than had hitherto been sought for.

Prof. Hackett points out the desirability of a clear specification of the objective of analyses of oscillator equations — whether knowledge of frequency or amplitude was the more important, for example.

The President, in agreement with this, suggests that the various methods might prove differently valuable in respect of different objectives. He also calls attention to the fact that « frequency » was in some cases somewhat ill-defined.

Le *Prof. Manneback* estime également qu'il serait nécessaire d'étudier une nouvelle définition de la fréquence. Il suggère de prendre comme mesure de la fréquence, la dérivée de la phase par rapport au temps, que la fréquence soit constante ou non, et de baser toute spécification de la fréquence sur cette dérivée.

Prof. Fortescue says that even the non-linear equation considered are too simple in form to correspond to many actual conditions of triode oscillation, and suggests that since operating conditions are controllable to some extent, it might be desirable to limit the practical conditions to those which were amenable to analysis.

The President agrees that such pratical simplification could be realised in many cases and gives an illustration from one of his earlier papers.

Finally, *the President* gives a brief account of an informal conference on the subject held in Paris in 1928. He says that non-linear differential equations are of importance in a number of fields — in engineering, aerodynamics, etc., as well as in radio, and it is the growing importance of the subject which has led him to include it in the U. R. S. I. programme. He hopes that it will receive due attention and that it will be possible to report further progress at the next meeting of the Union.

Assemblée Générale du mercredi 19 septembre

General Assembly held on Wednesday, September 19th

La séance est ouverte à 15,30 heures, sous la présidence du Dr. ECCLES, Vice-président de l'U. R. S. I.

The Chairman. — In opening this final meeting of the General Assembly we have to report first the doings of the Executive Committee, and the first item on our paper is to report certain alterations to the statutes that have been agreed by the Executive Committee.

Le *Cap. Dorsimont* donne lecture des modifications aux statuts adoptées par le Comité Exécutif (¹).

The Chairman. — The last alteration which M. Dorsimont has read really means that each Union in future is entirely free to adopt its own statutes. The exactment that the various Unions were subject to the statutes of the International Research Council is suppressed and therefore each Union is now free and independent of the International Council of Research. The alterations to our statutes which you have heard read need not therefore be submitted to the International Council. They are already in force.

Prof. Chapman. — Should not the alterations be ratified by the General Assembly ?

The Chairman. — We cannot find in the statutes, Prof. Chapman, any further direction as to the procedure in altering the statutes except that the whole of the organisation and administration is left in the hands of the Executive Committee. There is no requirement as to ratification, but it would be a very agreable thing if we could have the approval of the General Assembly to anything the Executive Committee has done. If members of the General Assembly wish to say anything about these alterations, they are welcome to do so.

(Les modifications aux statuts sont approuvées à l'unanimité).

The next thing is to receive reports of Presidents of Commissions. I am going to ask the President of each Commission to state what sub-committees have been formed, the purpose of each sub-committee, and, if he can, the personnel of each sub-committee, so that the General Assembly is fully informed of the future constitution of the Union.

Dr. Rayner, President of Commission I. —Commission I divided itself into two sub-commissions, one dealing with standards of frequency and similar subjects, and the other dealing with measurements of field strength. The one session was devoted to the first subject — frequency — and some interesting results were recorded by members of the Commission. I do not think that I need go over the ground again, but if I may put forward formally the resolutions of Commission I, Sub-Commission 1 (¹), which were agreed to this morning, I will do so. The paper is in the hands of the Congress and I do not propose to read the details, and I do not think translation will be necessary.

(¹) Voir p. 105.

(¹) See p. 108.

I formally move that the resolutions of Commission I, Sub-Commission 1, be adopted.

The second sub-commission, over which Dr. Smith-Rose presided, held three meetings to study the subject of the measurement of radiation field intensity. Some very interesting discussions and practical suggestions were made. The work divided itself among several ranges of frequency. The requirements of each range being somewhat different from those of the others. They decided it was desirable that the national laboratories should equip themselves with apparatus for verifying other apparatus for measuring field strength, and they suggested to the national laboratories a series of degrees of accuracy for five different frequency ranges suitable for the particular purpose for which those frequencies are used. They have succeeded in forming what I consider to be a very valuable table indicating the accuracy at which it is thought the national laboratories should aim in setting up apparatus of this character. The results of the deliberations are contained in five resolutions of Commission I, Sub-Commission 2, (1) Measurement of Field Strength, some of which deal with technical points which need not be entered into now. I therefore have pleasure in requesting the congress to adopt these 5 resolutions.

The Chairman. — I ask the Assembly if they approve of this report ? (*Approved.*)

Dr. Smith-Rose, Deputy of Dr. Dellinger, President of Commission II. — The work of Commission II was divided up into four sub-commission, and a fifth sub-commission was elected jointly with representatives of Commission V, to consider the theory of propagation in the ionosphere. The first of these four sub-commissions dealt with ionospheric measurements, and a series of resolutions (2), largely concerned with nomenclature and definitions, and finally containing a recommendation for the formation of a standing committee, have been adopted at the full session of Commission II. The constitution of the standing sub-committee which it is proposed to appoint is as follows : Prof. Appleton, Comm. Bureau, Dr. Dellinger, Dr. la Cour, M. Naismith, Dr. van der Pol, Mr. Watson-Watt.

It was agreed that the Chairman of this sub-committee had power to co-opt representatives from other countries not already represented.

The second sub-commission presided over by Mr. Heising dealt with sunspot relations. Two resolutions containing recommendations for the continuation of the work were adopted (1).

The third sub-commission under Dr. van der Pol dealt with the subject of the interaction of radio waves. A resolution (2) which has been adopted by Commission II recommends the formation of a sub-committee consisting of Mr. Picault, Mr. Kirke and Mr. Eckersley, to devise a range of certain experiments on the interaction of radio waves, Dr. van der Pol to receive and correlate the reports of those measurements.

The fourth sub-commission under the presidency of Prof. Chapman dealt with the relation with solar eclipses, and four resolutions, already circulated and adopted by the meeting of Commission II, were drawn up by that sub-commission.

There was a special commission set up last year to deal with the work of the International Polar Year. That has moved two resolutions which were adopted at the meeting of Commission II. A further resolution was proposed by Prof. Appleton in connection with the collection of data on magnetic activity, which was also adopted by Commission II.

The Chairman. — May I take it that the General Assembly approves this action on the part of Commission II. (*Approved.*)

Prof. Appleton, President of Commission III. —Our first sub-commission under Prof. Norinder's presidency made seven recommendations for increasing our knowledge of electric phenomena in the atmosphere (¹) and finally decided to appoint a committee under the presidency of Prof. Norinder, and including Mr. Watson-Watt and Dr. Schonland (in South Africa) to see that these resolutions were made known to workers likely to extend our knowledge in this particular field.

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(1) See p. 109. (2) See p. 110.

(1) See p. 113. (2) See p. 114.

The two sub-commissions on propagation and measurements were eventually combined into a single one with Comm. Bureau as President, and they made three resolutions dealing with such things as particular frequencies on which atmospherics were to be recorded (²). There will now be a sub-commission with Comm. Bureau as Chairman, Mr. Lugeon and Mr. Watson-Watt as other members. This sub-committee is to organize the recordings of atmospherics and suggest a way that the rate of generation of electric disturbances in all regions of the globe may ultimately be determined.

Next, Sub-Commission 4, direction-finding, put forward a number of resolutions dealing with the details of such work (³), and a sub-commission was appointed under Mr. Watson-Watt's chairmanship. This is a rather larger committee because it is for extending the work: Comm. Bureau, Dr. Friis, Dr. Lugeon, Prof. Norinder, Dr. Schonland, Prof. Wagner.

Another sub-commission was added to the ones shown on the board. This is a sub-commission of one member only, that is, Mr. Watson-Watt, to deal with all questions of interchange of data between interested workers in this particular field of atmospherics.

The Chairman. — Does the General Assembly approve of these resolutions ? (*Approved.*)

The Chairman. — Prof. Kennelly is the President of the Commission on Cooperation (IV). There has been one meeting and one resolution.

Dr. vander Pol, Deputy Chairman of Commission IV. — A resolution has been submitted and accepted this morning for Commission IV, and this resolution reads (¹). (Dr. van der Pol reads the resolution).

L'Assemblée Générale ratifie la résolution présentée par la Commission IV.

Dr. van der Pol, President of Commission V. — The Commission V was split up in three sub-commissions : 1) under the presidency of Prof. Mesny; 2) under the presidency of Prof. Wagner; 3) under my own presidency.

The first sub-commission considered the constitution of the higher atmosphere and also considered the questions arising in connection with the theory of the propagation of waves, and specifically it was discussed in the sub-commission under what circumstances the general wave theory can be simplified to a ray theory of propagation.

In the second sub-commission under Prof. Wagner detailed discussions took place on the generation of ultra-short waves and the problems connected therewith.

In the third sub-commission we had extensive discussions on the symbolic calculus and its application to radio, and on the non-linear theory of oscillations, and I think it was characteristic for our Commission V that we found that of all these problems we knew still very little, and that is the reason why in our resolutions (of the Commission V) (²) it was suggested that many of the questions already treated should be extended and treated again in the next assembly of the U. R. S. I.

We therefore propose five resolutions :

1. — Concerning further study of the generation of ultra-short waves: report to be made by Prof. Wagner and Prof. Mesny.

2. — Concerns the further study of the propagation of ultra-short waves below 10 m. : suggested study to include the determination of the effect of the atmosphere and of the earth.

(¹) See p. 115. (²) See p. 116. (³) See p. 117.

(¹) See p. 118. (²) See p. 119.

3. — Concerns a new subject for this meeting, although it was already discussed at Copenhagen; it is : A further theoretical and experimental study of Brownian movements of electrons in conductors and of the Shot effect in thermionic tubes. Mr. Llewellyn, Mr. Moullin and myself to prepare a report for the next Union.

4. — Further resolution, the theory of non-linear oscillations again to be considered and further advance to be reported. I was asked to prepare a report.

5. — This Commission jointly with Commission II desires the further investigation of the theory of propagation and absorption of waves etc. The Commission has asked Mr. Eckersley and Prof. Manneback to prepare a report on this subject.

The Chairman. — You have heard these recommendations. Do you approve them ?

L'Assemblée Générale approuve les résolutions proposées par la Commission V.

The Chairman. — The next business on our paper is to report the action of the Executive Committee and various changes in personnel of the Union. The first matter concerns the new Presidents of Commissions.

The arrangements made are :

Commission I. — Dr. Rayner, President.
Commission II. —Dr. Dellinger, President.
Commission III. — Prof. Appleton, President.
Commission IV. — No President appointed at present.
Commission V. — Dr. van der Pol, President.

I hope these have the approval of the General Assembly. (*Approved.*)

The Executive Committee have proposed the Vice-Presidents for the next period: Prof. Nagaoka, existing Vice-President, we recommend should continue in office; Prof. Mesny, recommended at the Paris meeting of the Executive Committee, confirmed at this meeting of the Executive Committee; Dr. Dellinger and Dr. van der Pol, two new Vice-Presidents, proposed at this meeting. I hope this has the approval of the General Assembly. (*Approved*).

The next item had better declared by the General Secretary, Dr. Goldschmidt.

Le *Secrétaire Général.* — Les statuts ne spécifient rien en ce qui concerne la nomination de Présidents d'Honneur, et cependant nous désirons beaucoup que l'Assemblée Générale vote la création de deux Présidents d'Honneur. Je vais vous dire pourquoi. Supposons par exemple que dans un pays tel que l'Angleterre, nous ayons l'intention d'offrir une place du Bureau à une certaine personnalité; il est impossible d'avoir un Président et un deuxième siège au Bureau occupé par un membre de la même nation. Dans le cas présent, nous aimerions en même temps avoir le Dr. Eccles comme Président, mais nous ne pouvons pas réaliser ce désir. Il existe cependant un moyen de tourner la difficulté en créant des Présidents d'Honneur. C'est l'objet de la proposition que nous vous soumettons et nous vous proposons d'offrir l'un de ces titres au Dr. Eccles et l'autre au Prof. Kennelly. (*Applaudissements.*)

The Chairman. — I am requested to put to the meeting that the action of the Executive Committee be approved. (*Approved.*)

On my own part I ought to say I appreciate extremely this great honour, and, as I told the Executive Committee, I appreciate it all the more because I am not deserving of it. A thing not merited is usually valued more highly than something that has been earned. This has come to me quite undeservedly, and I value it very highly, not on that account, but I value it doubly on that account. It shows the extreme kindness of the officials of the U. R. S. I. and their long memory of work I did long ago before the U. R. S. I. was formed. I thank you, gentlemen, very much (*Applause.*).

Le *Secrétaire Général.* — Nous remercions le Dr. Eccles d'avoir accepté notre offre. Elle est pleine de conséquences pour l'U. R. S. I.

Le Dr. Eccles ajoutera encore à la gloire de notre Union. (*Applaudissements.*)

The Chairman. — The next item is to announce the action of the Executive Committee in nominating a new President. They have proposed Prof. Appleton as President for the next period. I need not try to justify that appoitment. It would be painting the lily and doing all sorts of unnecessary things. We of the Executive Committee are very glad that Prof. Appleton will undertake the onerous duties of President during the coming period, and we know his reign will be a great succes. I ask you to approve with acclamation his nomination. (*Applause.*)

Prof. Appleton. — Mr. President, Gentlemen : I thank you very much indeed for the great honour you have done me in making me President of the Union. I have in mind, of course, the great qualifications of my predecessors, of General Ferrié, Dr. Austin, Prof. Kennelly, and I think we ought to include in our line of Presidents Dr. Eccles himself. We have all admired the sagacious way he has presided over our activities, and I regard him as one of my predecessors in office. In accepting office, I feel encouraged to do so because of the help which I know I can count on from various sources. For example, I know I can count on Dr. Goldschmidt, who is in every sense of the word the father of our Union, (*Applause*), besides being, Gentlemen, as I have recently learned, the real father of broadcasting. Then I can count on Capt. Dorsimont, who always seems to be there in readiness to help anyone. And I think I can count on all of those who have been here this meeting. It seems to me that co-operation has been the watch-word throughout this gathering. If I can win from you anything like the affectionate regard you have accorded to my predecessors, I shall be very proud indeed. (*Applause.*)

The Chairman. — That concludes the business of this part of the meeting. We will have tea outside and return to run through a series of formal motions which are necessary to our business, which can be carried through fairly rapidly.

La séance est suspendue pendant 15 minutes.

The Chairman. — Ladies and Gentlemen, I will open this meeting by reading to you a cable I have received from Prof. Kennelly in reply to the message we sent to him expressing our sympathy with him on his illness and wishing him a speedy recover.

« Deeply appreciate kind message of sympathy. Good wishes to all members. I feel assured of successful meeting ».

Now our business this afternoon is to propose a series of votes of thanks to all the people who have been hospitable to the U. R. S. I. during its visit to London. I will call first upon Prof. Mesny to propose the vote of thanks to the Royal Society for their hospitality. (*Applause.*)

Le *Prof. Mesny.* — Mesdames, Messieurs, nous sommes arrivés à la fin de nos travaux et nous avons maintenant le loisir et le devoir de considérer les conditions dans lesquelles nous avons travaillé. Comme l'a fait remarquer notre Président, l'importance de l'œuvre de l'U. R. S. I. va en grandissant, mais nous ne devons pas oublier qu'outre le travail personnel de chacun des membres de l'Union, les conditions matérielles dans lesquelles nous nous sommes trouvés ont joué un rôle considérable en facilitant notre tâche. Grâce à la Royale Society, nous avons trouvé ici, des locaux parfaitement adaptés au travail que nous avions à faire. Nous la remercions d'autant plus chaleureusement que nous sommes très encombrants, très bruyants et par conséquent peu désirables. La Royale Society fait plus que de nous placer dans d'excellentes conditions, elle a installé nos réunions dans des salles merveilleuses où nous avons travaillé sous l'égide encourageante de tous les savants de l'Angleterre : ici même, le plus grand de tous, Newton qui surveille au cours des siècles, les progrès de la science qu'il a si magistralement mise en marche, préside à notre dernière séance. (*Applaudissements.*)

Dr. Eccles. — I take it from your applause that this resolution is heartily agreed. (*Agreed.*)

Fortunately we have Sir Henry Lyons, Treasurer of the Royal Society, with us. He may respond (*Applause*).

Sir H. Lyons. — Mr. President, Ladies and Gentlemen. The President of the Royal Society has desired me to express to you his regret that he is unable to be present at your final meeting, and I am sure that he and the Council will be extremely pleased to learn from Prof. Mesny's speech that the facilities which the Society has been able to place at your disposal have been sufficient and satisfactory. It is almost 16 years ago since a group of scientific men met in this room to discuss how it might be possible to reform international scientific organisations, and the outcome of that was that some 7 or 8 international unions have been since organised. I do not think that there is any of those unions that can show a finer record of high scientific achievement than can the International Scientific Radio Union. It has so wide a field and has covered it so effectively in the time at your disposal that I am sure even greater results await you. On behalf of the President and Council of the Royal Society I beg to convey to you our best wishes and the hope that your future may be even more successful than has been the past. Thank you, Gentlemen ! (*Applause.*)

Dr. Eccles. — Now the next item is a vote of thanks to the President of Commissions, the reporters and the interpreters. I will not name them individually, it is a very long list. I will simply say that we can scarcely express our indebtedness to the various presidents and other officials in ordinary words. Their labours have been so prodigious, especially at this Congress more than at any previous Congress, their labours have been so great that anything I can say is perfectly inadequate. I ask you to accept this motion o thanks to the Presidents of Commissions, reporters and interpreters with acclamation. (*Applause*).

Then another body of workers we wish especially to thank is the clerical staff. I will ask Dr. Rayner, who knows most about this, to speak.

Dr. Rayner. — I have a most pleasant duty to perform in expressing our most sincere thanks to our clerical staff for their help. Not only has my personal assistant, Miss Mercer, helped me in the organisation of the meetings during the past year, and has known many of you by name, but during the last week she and other members of the staff have worked early and late to help us.

A Congress of this kind depends for its existence on the typewriting machine and its operators. Wat the first Polar Year people did without typewriters I cannot imagine. There were no such machines in existence. Three of the staff have been put at our service by the National Physical Laboratory and two by the British Standards Institution. They are all accustomed to technical electrical work, which makes a great difference in the accuracy and correctness of the reports which you receive. I ask you to give them your most sincere thanks. At the opening session I said their one object was to serve you, and this they have done in full measure. (*Applause.*)

Dr. Eccles. — I put that to the meeting formally. (*Agreed.*)

Our next act of gratitude is to the Ladies' Committee and I will ask Madame Mesny to propose the vote of thanks (*Applause*).

Madame Mesny monte sur l'estrade, mais trop émue, elle ne peut prononcer l'allocution suivante :

Mesdames, Messieurs,

Au nom des dames étrangères qui ont été assez heureuses pour accompagner leurs maris, je viens vous exprimer notre reconnaissance pour l'accueil que nous avons reçu.

Vous n'avez rien négligé pour nous faire connaître le très beau caractère de votre magnifique pays; croyez bien que nous en conserverons précieusement le souvenir. Mais laissez-moi vous dire que l'admiration que nous avons éprouvée pour tout ce que nous avons vu, est dépassée par l'émotion que nous a causée votre cordialité ; dès le premier jour nous avons eu l'impression de nous trouver en famille — at home — et je ne crois pas qu'il y ait de sentiment plus doux, surtout pour une femme.

Nous regrettons d'interrompre si tôt d'aussi charmantes relations et nous souhaitons de vous rencontrer nombreuses aux prochaines réunions de l'U. R. S. I. Nous espérons que, guidées par votre exemple, nous saurons donner à votre séjour chez nous le même cachet de gaîté franche et de sincère amitié. (*Applaudissements.*)

Mrs. Appleton. — I understand perfectly what Madame Mesny wants to say. I do not know much French, in fact I know very little, and on the first day when we met these ladies we all looked rather strained, and I myself was very frightened, but you see to-day we are not frightened, we understand one another perfectly without words. Many friendships have been formed, and I am sure all the English ladies would wish me to say how we have loved having you here in London. I heard the English ladies say that not only have they enjoyed themselves enormously, but they have learned a lot more French in a much more pleasant way than one usually learns at school. We shall all remember this conference as long as we live, and I hope that we shall all meet again at the next conference, perhaps, so that we may strengthen the friendship so charmingly formed in England. We all wish you « bon voyage » and « au revoir » ! (*Applause.*)

Dr. Eccles. — I put the vote to the meeting. (*Approved.*)

The next item is to convey our thanks to various official bodies who have welcomed us and entertained us. In the first place there is the Government itself then we have sections or departments of the Government, and then other institutions. I will merely read the list. It will be arranged, of course, that each of the authorities named will be communicated with and a formal vote of thanks sent to them, but I will read the list and ask you to approve a vote of thanks from the Chair.

Those to whom we must send our thanks are : H. M. Government, the Post-Master General, the Director of National Physical Laboratory, the British Broadcasting Corporation, the Royal Institution and St. Johns College, Cambridge. Those in favour of this motion, will they please hold up their hands. (*Approved.*)

The next vote on the paper is thanks to the Chairman and members of the British National Committee, who have had all the preparation of the visit of the congress to London during the past year or more. I will ask Dr. Goldschmidt to propose that motion.

Dr. Goldschmidt. — Je crois être l'interprète de tous en demandant de voter des remerciements au Président et aux Membres du Comité National Britannique. (*Applaudissements.*)

Prof. Appleton. — Ladies and Gentlemen, It will give me great pleasure to transmit this message of thanks to my own committee, the British National Committee.

In regard to the conference, it seems to me that its success has depended on four principal things. First, to have the privilege of working in these rooms; secondly, on the staff work of our Secretary General; thirdly, on our being able to call upon the staff of he National Physical Laboratory as secretaries, Government whips, and so on, for our sub-commissions ; and finally I think we must single out for special mention Dr. Rayner and his family. (*Applause.*) The way in which things have gone has reminded me of an analogy with the mathematical function of which all points are known. There never appears to have been a discontinuity in the curve. There has at no point been a need for extrapolation, the function was continuous all the time. (*Applause.*) It will give me great pleasure to transmit this vote of thanks to my own National Committee in the near future.

Dr. Rayner. — I thank you, Prof. Appleton. During the last few months, and particularly during the last week, I have had the great pleasure of attempting to be of service to others. That pleasure is increased by knowing that by the aid of other members of the National Committee and ladies and friends especially Mrs. Appleton and Mrs. Watson-Watt, we have not failed. We have endeavoured to show you beautiful and historic parts of England. We have succeeded in arranging visits, each of which will long remain in your memory. We have made new friends whom we shall not forget. Some of us knew some of you as a result of attending previous meetings of the U. R. S. I., but many have met you for the first time. We thank you for coming. We are sorry that you must leave so soon, but we feel that we have gained something that we shall never lose the acquaintance of friends to whom our little services during the past week have been of value, and who will long remember this visit to London as one of the events of their lives.

Dr. Eccles. — I will call upon Dr. van der Pol to propose a motion.

Dr. van der Pol. — It is my privilege to move a vote of thanks to Dr. Eccles, acting President, and I do so with the greatest pleasure. I have known Dr. Eccles already I think 18 years, and not only Dr. Eccles but also Mrs. Eccles. It was, I think, in 1916 or 1917 that we had quite an interesting discussion in his rooms on what we now all regard as very classical work, the theory of the propagation of radio waves through the atmosphere. And on that occasion we planned some experiments to verify this classical theory of Dr. Eccles. It was in the days of the war and I was working in London, and there were difficulties in obtaining for such experiments radio valves. And I remember that in Dr. Eccles' room — he was sitting at one side of the table and I at the other — there were three valves on the table, and he said to a foreigner « take them along ». These were the first valves I ever got, and later on, after the armistice I went home to Holland, and I smuggled those three valves in a pair of socks to Holland, or rather out of England. It is a great honour for me now to move a vote of thanks to Dr. Eccles, acting President. Everyone present here is impressed by his wise guidance, and I am sure you will all accept this motion of thanks to Dr. Eccles. (*Applause.*)

Dr. Eccles. — I need say very little in thanking Dr. van der Pol and the meeting for this kind vote of thanks. As Dr. van der Pol says, I was in radio when first he came to England 18 years ago, and even before that. I suppose I entered in 1899, which is 35 years ago. And it is because I am perhaps the senior of all the members of the U. R. S. I. that I was asked to step Prof. Kennelly's place. There are very few who can be older, but perhaps M. Jouaust can date to nearly the same epoch, but as the senior member of the U. R. S. I. it was a duty to step into the breach. I regard it also as a great honour, and if I have been able to carry out the work of the President to our satisfaction I am extremely glad. The work has been to me a very great pleasure, because it has enabled me to meet a large number of old friends whom I might not otherwise have seen so often this week as I have done as President, and it has enabled me to make a great many new friends. As President one does not need an introduction, and therefore I think I have approached most of the members of the Congress during the past ten days and learned something about them. I am very glad to have made so many friends in this Congress during the ten days of office I have enjoyed. I have to thank Dr. van der Pol very much and you, Ladies and Gentlemen, for this vote of thanks.

Now the last act of our proceedings is to ask Dr. Goldschmidt to make a final statement. (*Applaudissements.*)

Dr. Goldschmidt. — Je ne vais pas faire un discours, mais je tiens à adresser des remerciements à tous ceux qui ont collaboré à la réussite de l'Assemblée Générale. S'il y en a parmi eux qui ont été oubliés ou trop peu remerciés, qu'ils se consolent en pensant qu'ils ont coopéré à un travail très important qui aura une répercussion durable pour la science. En terminant je souhaite à l'U. R. S. I. « many happy returns ». (*Applaudissements.*)

Dr. Eccles. — This Congress is now concluded.

Résolutions adoptées par l'Assemblée Générale

Resolutions carried by the General Assembly

COMITÉS EXÉCUTIF ET FINANCIER

FINANCIAL AND EXECUTIVE COMMITTEES

1. — Modifications aux Statuts de l'U. R. S. I.

Chapitre I. — Le *titre* du chapitre : « Objets de l'Union et conditions d'admission » devient : « Objets de l'Union ».

L'*article* 2 : « L'admission d'un pays à l'Union est subordonnée aux conditions fixées par les statuts du Conseil International de Recherches » est supprimé.

Chapitre III. — L'*article* 7 : « Le Bureau de l'Union comprend un Président, des Vice-Présidents et un Secrétaire Général élus par l'Assemblée Générale » est complété par le paragraphe suivant : « Le Président entre en fonction après l'Assemblée Générale qui a prononcé son élection et y demeure jusqu'à la fin de l'Assemblée Générale suivante. Il est immédiatement rééligible ».

Le 2e *alinéa* de l'*article* 7 : « Tous les Membres du Bureau devront appartenir à des nations différentes. Ils demeurent en fonction jusqu'à la fin de la 2e Assemblée Générale ordinaire qui suit celle de leur élection » est modifié comme suit : « Tous les Membres du Bureau devront appartenir à des nations différentes. Ils demeurent en fonction jusqu'à la fin de l'Assemblée, Générale ordinaire qui suit celle de leur élection ».

Chapitre IV. — L'*article* 9 : « Le Président et les Membres de chacune de ces Commissions sont élus par l'Assemblée Générale sur propo-

1. — Modifications to the Statutes of the U. R. S. I.

Chapiter I. — The *title* of the chapter : « Objects of the Union and Conditions of Admission » to become : « Objects of the Union ».

Article 2 : « The admission of countries to the Union shall be subject to the regulation of the International Research Council » to be suppressed.

Chapter III. — *Article* 7 : « The Bureau of the Union shall consist of a President, Vice-Presidents and a General Secretary, who shall be elected by the General Assembly » to be completed by the following paragraph : « The President shall hold office after the General Assembly by which he has been elected until the end of the following ordinary General Assembly. He shall be immediately re-eligible ».

Second paragraph of *article* 7 : « All the members of the Bureau shall have to be from different countries. They shall hold office until the end of the second ordinary General Assembly following that of their election » to be changed as follows : « All the Members of the Bureau shall have to be from different countries. They shall hold office until the end of the ordinary General Assembly following that of their election ».

Chapter IV. — *Article* 9 : « The President and the Members of the Commissions are elected by the General Assembly on the nomisition du Comité Exécutif de l'Union. Ils restent en fonctions jusqu'à la fin de l'Assemblée Générale ordinaire suivante et sont rééligibles » est modifié et complété comme suit : « Le Président de chacune de ces Commissions est élu par l'Assemblée Générale sur proposition du Comité Exécutif de l'Union. Il reste en fonction jusqu'à la fin de l'Assemblée Générale ordinaire qui suit celle de son élection et est immédiatement rééligible. Les Membres des Commissions sont désignés par le Comité Exécutif ».

CHAPITRE VI. — L'*article* 14 : L'Union se réunit au minimum tous les deux ans en Assemblée Générale » est modifié comme suit : « L'Union se réunit si possible tous les deux ans en Assemblée Générale ».

CHAPITRE VII. — L'*alinéa* 5 de l'*article* 18 : « Les protectorats diplomatiques et pays sous mandat jouissent du même droit » est modifié et complété comme suit : « Les protectorats diplomatiques, pays sous mandat et les colonies ayant un budget indépendant, jouissent du même droit. Leur cotisation sera fixée par le Comité Exécutif en tenant compte de leur activité scientifique ».

2. — Nominations

à la *Présidence d'Honneur* de l'Union : MM. le Dr. W. E. Eccles et le Prof. A. E. Kennelly.

à la *Présidence* de l'Union : M. le Prof. E. V. Appleton,

aux *Vice-Présidences* de l'Union : MM. le Dr. J. H. Dellinger, Prof. R. Mesny, Prof. H. Nagaoka, Dr. B. van der Pol,

au *Secrétariat-Général* de l'Union : M. le Dr. R. B. Goldschmidt,

aux *Présidences des Commissions* :

Commission I. — Méthodes de Mesures et Etalonnages : M. le Dr. E. H. Rayner (Grande-Bretagne),

Commission II. — Propagation des Ondes : M. le Dr. J. H. Dellinger (Etats-Unis),

nation of the Executive Committee of the Union. They hold office until the conclusion of the ordinary meeting of the General Assembly following that of their election, and are re-eligible » to be modified and completed as follows: « The President of each Commission is elected by the General Assembly on the nomination of the Executive Committee. He shall hold office until the conclusion of the ordinary meeting of the General Assembly following that of his election, and is re-eligible. The members of the Commissions are nominated by the Executive Committee ».

CHAPTER VI. — *Article* 14 : « The Union shall hold an ordinary meeting of the General Assembly at least once every two years » to be modified as follows : « The Union shall hold an ordinary meeting of the General Assembly once every two years if possible ».

CHAPTER VII. — *Paragraph* 5 of *article* 18 : « The diplomatic protectorates and countries under mandate have the same power » to be modified as follows : « The diplomatic protectorates, countries under mandate and colonies having their own budget, have the same power. Their contributions shall be determined by the Executive Committee, owing to their scientifical activity ».

2. — Nominations

as *Honorary Presidents* of the Union : Dr E. W. Eccles and Prof. A. E. Kennelly,

as *President* of the Union : Prof. E. V. Appleton,

as *Vice-Presidents* of the Union : Dr. J. H. Dellinger, Prof. R. Mesny, Prof. H. Nagaoka, Dr. B. van der Pol,

as *General Secretary* of the Union : Dr. R. B. Goldschmidt,

as *Presidents of Commissions* :

Commission I. — On Measurements and Standartisation : Dr. E. H. Rayner (Great-Britain),

Commission II. — On Radio-Wave Propagation Dr. J. H. Dellinger (U. S. A.), Commission III. — Perturbations Atmosphériques : M. le Prof. E. V. Appleton (Grande-Bretagne),

Commission IV. — Liaison (Amateurs, Opérateurs, Praticiens et Sciences Connexes) : N...

Commission V. — Radiophysique : M. le Dr. B. van der Pol (Pays-Bas),

à la *Présidence du Comité Exécutif* : Il est décidé que le Président en fonctions présidera le Comité Exécutif.

3. — Représentation de l'U. R. S. I. auprès d'autres Groupements Scientifiques

Le Dr. E. H. Rayner est désigné pour représenter l'U. R. S. I. au sein du Comité des Instruments et Mesures.

4. — Fusion des Comités Exécutif et Financier

Il est décidé de fusionner en un seul les Comité Exécutif et Financier.

5. — Références Bibliographiques

Il est décidé de continuer le service des Références Bibliographiques sous une forme réduite.

6. — Démarches

Le Secrétariat Général est chargé :

a) de poursuivre les démarches en vue de l'adhésion de l'Allemagne ;

b) d'effectuer toutes les démarches nécessaires en vue de l'adhésion de nouveaux pays.

7. — Publication des Comptes-rendus

Le Secrétariat Général est chargé de publier les comptes rendus de l'Assemblée Générale en y rapportant les débats, les propositions concrètes des Commissions et le résumé des mémoires scientifiques présentés à l'Assemblée.

8. — Gestion Financière

L'exposé financier et les comptes des exercices 1931-1932, 1932-1933, 1933-1934 sont approuvés et décharge est donnée au Secrétaire Général de sa gestion. Son mandat est renouvelé à l'unanimité.

Commission III. — On Atmospherics : Prof. E. V. Appleton (Great-Britain),

Commission IV. — On Co-operation (Amateurs, Operators, Practioners and Connected Sciences) : N...

Commission V. — On Radiophysics : Dr. B. van der Pol (Holland),

as *President of the Executive Committee* : The holding office President shall be President of the Executive Committee.

3. — Representation of the U. R. S. I. by other Scientifical Societies

Dr. E. H. Rayner is nominated in order to represent the U. R. S. I. at the Comité des Instruments et Mesures.

4. — Fusion of the Executive and Financial Committees

The fusion of the Executive and Financial Committees in one Committee is decided.

5. — Bibliographical References

It is agreed to continue the service of Bibliographical References in a reduced way.

6. — Steps to Undertaken

The General Secretary is required :

(*a*) to continue to act in view to obtain the adhesion of Germany ;

(*b*) to undertake the necessary steps to obtain the adhesion of new countries.

7. — Publication of Accounts

The General Secretary is required to publish the accounts of the General Assembly, countaining the meetings, the proposals of the Commissions and the summaries of the scientifical documents presented to the General Assembly.

8. — Financial Administration

The financial statement and the accounts of the exercises 1931-1932, 1932-1933, 1933-1934 are approved and discharge is given to the General Secretary of his administration. His mandate is unanimously renewed.

COMMISSION I

Sous-Commission 1. — Étalons de Fréquence

Sub-Commission 1. — Frequencies Standards

1. Il serait désirable que l'on continue l'étude du perfectionnement des appareils destinés à maintenir la plus grande constance possible dans la fréquence des oscillations. Les méthodes expérimentées en vue de la Radio ne peuvent manquer d'être utiles dans d'autres branches de la science, telles que l'astronomie et la géodésie. Il conviendrait de développer la collaboration avec les organisations qui s'intéressent à ces questions.

2. Il conviendrait de continuer les comparaisons d'étalons de fréquence, par des mesures de la fréquence des modulations et de l'onde porteuse.

3. Il est à désirer que l'on profite de l'offre faite par la station de Rugby qui a une portée mondiale, pour effectuer des mesures de fréquence et d'autres expériences de ce genre, lorsqu'on entreprend un travail important et que l'on peut utiliser des méthodes techniques convenables. L'utilisation de cette station promet de faciliter les travaux géodétiques.

4. Il conviendrait de continuer la modulation simultanée de deux ou plusieurs fréquences porteuses par un même source modulatrice, de façon à arriver à une connaissance plus approfondie des phénomènes physiques de la transmission. On devrait effectuer des observations simultanées des grandeurs magnétiques.

5. On recommande d'effectuer des comparaisons internationales des méthodes et des appareils de mesure des courants à haute-fréquence.

1. The development of apparatus for the maintenance of oscillation frequencies of the greatest possible constancy should be continued. The methods which have been developed for radio purposes cannot fail to be of value for other branches of science, such as astromony and geodesy; and collaboration with organisations associated with these subjects should be further developed.

2. International comparisons of standards of frequency should be continued by measurements of the modulation frequency and carrier frequency.

3. It is desired to take advantage of the offer of the Rugby Station with its world wide range for frequency measurements and similar purposes, when important work is in progress and suitable technical methods are available. Geodetic work promises to be greatly facilitated by its use.

4. The modulation of two or more carrier frequencies simultaneously by the same modulation source should be continued, to provide further knowledge of the physics of radio transmission. Simultaneous observations of magnetic quantities should be made.

5. It is recommended that international comparisons should be made of methods and apparatus for the measurement of current at high frequencies.

Sous-Commission 2. — Mesure de l'Intensité du Champ

Sub-Commission 2. — Measurement of Field Strength Intensity

1. Que l'U. R. S. I. continue l'étude des méthodes de mesure de l'intensité du champ aux radio-fréquences.

2. Que l'on demande aux différents laboratoires nationaux d'établir des étalons d'intensité du champ et que l'on fasse des démarches en vue de la réalisation de comparaisons de ces étalons.

3. Que les valeurs des champs à mesurer et les précisions à atteindre dans les appareils étalons soient conformes au tableau ci-dessous :

Longueur d'onde m.	Fréquence kc/s.	Champ minimum µV/m.	Précision pour le Champ minimum	Champ maximum µV/m.	Précision (1) pour le Champ maximum
			%		%
plus de 2000	moins de 150	1.0	± 5.0	10^6	± 1
2000-200	150-1500	1.0	± 5.0	2×10^6	± 1
200-60	1500-5000	1.0	± 5.0	10^5	± 5
60-10	5000-30.000	0.1	± 20	10^5	± 5
moins de 10	plus de 30.000	10	± 20	10^5	± 10

4. Que les appareils étalons pour la mesure de l'intensité du champ soient dotés d'une antenne en boucle pour les longueurs d'onde dépassant 15 m., et d'un dipole orientable pour les longueurs inférieures à 15 m. Le système à boucle sera établi de façon à maintenir la valeur du champ au centre de la boucle quelle que soit sa situation.

5. Que l'on continue l'étude des hauteurs et des longueurs effectives des antennes ouvertes et des dipoles. Cette étude est nécessaire pour deux motifs : (*a*) Les connaissances actuelles ne justifient pas la spécification de la nature,

1. That the U. R. S. I. continue the study of methods of measuring field intensity at radio frequencies.

2. That the several national laboratories be asked to set up field intensity standards, and that steps be taken if possible to make intercomparisons of these.

3. That the ranges of fields to be measured and the accuracies to be aimed at in the standard apparatus should be as shown in the following table :

Wavelenght m.	Frequency kc/s.	Minimum Field. µV/m.	Accuracy at Minimum Field	Maximum Field. µV/m.	Accuracy (1) at Maximum Field.
			%		%
Above 2000	Below 150	1.0	± 5.0	10^6	± 1
2000-200	150-1500	1.0	± 5.0	2×10^6	± 1
200-60	1500-5000	1.0	± 5.0	10^5	± 5
60-10	5000-30.000	0.1	± 20	10^5	± 5
Below 10	Above 30.000	10	± 20	10^5	± 10

4. That the standard apparatus for the measurement of field strength be fitted with a loop aerial for wave-lengths exceeding 15 m., and with a dipole capable of orientation for wave-lengths less than 15 m. The loop apparatus shall be such as to yield the value of the field at the centre of the loop, wherever this may be placed.

5. That the study of the effective heights and lengths of open aerials and dipoles be continued. This is required for two reasons: (*a*) Present knowledge does not justify specification of the nature, dimensions, height above

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(1) Il conviendrait de conserver les précisions fixées pour les champs maxima jusqu'aux valeurs décroissant jusqu'à 1000 µV/m.

(1) It is desirable that the accuracies specified above for the maximum fields should be maintained for field strengths down to 1,000 µV/m.

des dimensions, de la hauteur au-dessus du sol, ni du mode de couplage du récepteur au dipole à utiliser comme il est indiqué au 4 ; (*b*) Certaines discordances dans les résultats de la mesure de l'intensité du champ avec des antennes ouvertes, aux grandes et aux moyennes longueurs d'ondes, sont attribuées au manque de connaissances exactes de la hauteur effective de telles antennes.

ground and manner of coupling to the receiving set of the dipole to be used as in 4 ; (*b*) Certain discrepancies in the results of measurement of field strength with open aerials at medium and long wave-lengths are attributed to lack of precise knowledge of the effective height of such aerials.

COMMISSION II

Sous-Commission de l'Année Polaire Internationale

International Polar Year Sub-Commission

1. Une copie des Instructions concernant le Radio-Programme de la Deuxième Année Polaire Internationale devrait être conservée dans les archives de l'Union.

1. A copy of the Instructions issued relating to the Radio programme of the Second International Polar Year should be preserved in the archives of the Union.

2. Une copie de toutes les études relatives aux observations radioélectriques faites pendant la Deuxième Année Polaire Internationale devrait être envoyée au Bureau de la Commission Internationale.

2. A copy of all published papers relating to Radio observations made during the Second International Polar Year should be sent to the Bureau of the International Commission.

Sous-Commission 1. — Mesures de l'Ionopshère

Sub-Commission 1. — Ionosphere Measurements

1. Que le terme « Ionosphère » soit adopté avec la définition donnée plus bas.

1. That the term « Ionosphere » be adopted with the definition given below.

2. Définition de l'Ionosphère :

L'Ionosphère est la partie de la haute atmosphère suffisamment ionisée pour influencer la propagation des ondes électro-magnétiques.

2. Definition of « Ionosphere » :

The ionosphere is that part of the upper atmosphere which is sufficiently ionised to affect the propagation of wireless waves.

3. Que le terme « région » (et non pas « couche ») soit employé en relation avec l'ionosphère.

3. That the term « region » (and not « layer ») be used in connection with the ionosphere.

4. Que l'expression « group delay » soit utilisée dans les textes anglais pour désigner le temps mis par les signaux pour effectuer le trajet aller et retour de l'ionosphère.

4. That « group delay » be used for the time taken by pulse signals in their travel up to and down from the ionosphere.

5. Que les termes hauteur « virtuelle » ou « équivalente » soient utilisés pour désigner la moitié du produit du « group delay » par la vitesse de la lumière dans le vide.

6. Que les symboles suivants soient admis :
P pour le trajet optique,
P' pour le trajet virtuel ou équivalent,
f pour la fréquence.

7. Que les recommandations suivantes soient faites en vue des enregistrements internationaux intéressant l'ionosphère :

a) *Enregistrement de P'-t.*

Sur 3 Mc/s.

Moments des observations : 1er priorité-jours de 1er et 2e ordres (1). Recommandation générale : enregistrements continus.

On recommande également, si possible, la détermination de la polarisation.

b) *Enregistrement de P'-f.*

Moments des observations : Tous les jours internationaux au midi local. Recommandation générale : enregistrements à faire chaque jour.

c) *Enregistrement de P'-f* (*essais de* 24 *heures*).

Moments des observations : 4 fois par an : aux solstices et aux équinoxes. Recommandation générale : les jours des 3e et 4e ordres.

d) *Enregistrement automatique de P'-f.*

Aucune gamme de fréquences n'est déterminée. Les différents pays établiront eux-mêmes leurs propres fréquences en tenant compte de leur latitude.

Pour l'enregistrement de *P'-t*, si la fréquence de 3 Mc/s. n'est pas utilisable, on pourra effectuer les mesures soit sur 2 Mc/s., soit sur 4 Mc/s., soit sur ces deux fréquences.

8. Que l'on cherche à obtenir l'accord des administrations nationales pour que les émissions sur 3 Mc/s. soient réservées aux mesures internationales de l'ionosphère.

5. That the trems « virtual » or « equivalent » be used for the product of group delay and the velocity of light.

6. That the following symbols be agreed, viz :
P for optical path,
P' for virtual or equivalent path,
f for frequency.

7. That the following recommendations for International Ionosphere Recording should be made :

(*a*) *P'-t recording.*

On 3 Mc/s.

Times of observation : 1st priority — 1st and 2nd order days (1). General recommendation : Continuously.

There was also a recommendation for polarisation discrimination, if possible.

(*b*) *P'-f recording.*

Times of observation : All international days at local noon. General recommendation : Daily.

(*c*) *P'-f recording* (24 *hour tests*).

Times of observation : 4 times per year. General recommendation : 3rd and 4th order days.

(*d*) *Automatic P'-f recording.*

No frequency range specified. Different countries to settle their own frequency having regard to latitude.

For *P'-t* recording, if 3 Mc/s. prohibited, work may be carried on 2 Mc/s. and or 4 Mc/s.

8. That authority should be sought from national administration for sanction of the use of 3 Mc/s. for international ionospheric measurements.

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(1) Voir definition p. 112.

(1) See definition p. 112.

9. *Nomenclature.*

Que l'on convienne d'employer les notations suivantes pour les fréquences critiques des régions de l'ionosphère :

f_{E_1}, f_{E_2}, f_{F_1}, f_{F_2}, etc.

Les fréquences critiques des rayons ordinaire et extraordinaire seraient représentées par :

$f^o_{E_1}$, $f^x_{E_1}$, etc.

9. *Nomenclature.*

That the following terms for critical frequencies of the regions of the ionosphere be agreed :

f_{E_1}, f_{E_2}, f_{F_1}, f_{F_2}, etc.

Critical frequencies of ordinary and extraordinary rays should be denoted thus :

$f^o_{E_1}$, $f,^x_{E_1}$etc.

10. La Sous-Commission préconise également la création d'un Comité Permanent s'occupant des questions suivantes :

a) tenue d'un répertoire des différentes stations effectuant des mesures de l'ionosphère,
b) publication des programmes de travaux,
c) organisation d'observations spéciales à l'occasion d'éclipses, de manifestations météorologiques, etc.,
d) organisation de l'échange des résultats,
e) collationnement des résultats concernant le fonctionnement des circuits radioélectriques commerciaux, en vue de leur comparaison avec les résultats de l'ionosphère, et
f) établissement d'un rapport pour la prochaine Assemblée Générale.

10. The Sub-Commission also recommends the formation of a Standing Committee with the following duties :

(a) to keep a register of the different stations making ionospheric measurements,
(b) to issue the agreed programmes of work,
(c) to arrange special observations on the occasions of eclipses, meteoric displays, etc.,
(d) to arrange for the interchange of data,
(e) to collect data concerning the operation of commercial radio circuits for comparison with ionospheric data, and
(f) to report to the next General Assembly.

ANNEXE. — ADDENDA

Les journées de 1er et 2e Ordres de priorité dont question à la résolution 7, sont analogues à celles adoptées pour la Deuxième Année Polaire Internationale, et elles ont été définies, dans la lettre circulaire nº P. 1 de la Sous-Commission de l'Année Polaire en date du 15 février 1932. Cette définition est la suivante :

La Journée Internationale est supposée commencer le mercredi à 1600 *T. M. G.* pour finir le jeudi à 1600 T. M. G.

Les Journées Internationales de Premier Ordre correspondent, chaque mois du calendrier du premier mercredi à 1600 T. M. G. au jeudi à 1600 T. M. G.

Les Journées Internationales de Deuxième Ordre sont celles se présentant quatorze jours après les Journées de Premier Ordre, telles qu'elles ont été définies plus haut.

The days of first and second Order priority referred to in resolution 7 are similar to these already adopted in connection with the Second International Polar Year, and defined in circular letter No. P. 1 of the Polar Year Sub-Commission, dated 15th February 1932, viz :

The International Day is taken as beginning at 1600 *G. M. T.* Wednesday and ending at 1600 G. M. T. Thursday.

International Days of the First Order are the first incidence in each calendar month of 1600 G. M. T. Wednesday to 1600 G. M. T. Thursday.

International Days of the second Order are those occuring fourteen days after days of the First Order, as defined above.

Les Journées Internationales de Troisième Ordre sont celles prenant place entre les Journées Internationales de Premier et Deuxième Ordres.

Les Journées Internationales de Quatrième Ordre sont celles se présentant quatorze jours après les Journées de Troisième Ordre telles qu'elles ont été définies plus haut.

Liste des Journées Internationales de 1^er^ *et* 2^e^ *Ordres.*

Janv.	9/10	
	23/24	
Févr.	13/14	
	27/28	
Mars	13/14	
	21/22	Observation Spéciale de l'Equinoxe
	27/28	
Avr.	10/11	
	24/25	
Mai	8/9	
	22/23	
Juin	12/13	
	22/23	Observation Spéciale du Solstice
Juil.	10/11	
	24/25	
Août	14/15	
	28/29	
Sept.	11/12	
	23/24	Observation Spéciale de l'Equinoxe
Oct.	9/10	
	23/24	
Nov.	13/14	
	27/28	
Dec.	11/12	
	22/23	Observation Spéciale du Solstice

International Days of the Third Order are those occuring between International Days of the First and the Second Order.

International Days of the Fourth Order are those occuring fourteen days after Days of the Third Order as defined above.

List of the 1*st and* 2*nd Order International Days.*

Jan.	9/10	
	23/24	
Feb.	13/14	
	27/28	
Mar.	13/14	
	21/22	Special Equinox Observation.
	27/28	
Apr.	10/11	
	24/25	
May	8/9	
	22/23	
June	12/13	
	22/23	Special Solstice Observation.
July	10/11	
	24/25	
Aug.	14/15	
	28/29	
Sept.	11/12	
	23/24	Special Equinox Observation.
Oct.	9/10	
	23/24	
Nov.	13/14	
	27/28	
Dec.	11/12	
	22/23	Special Solstice Observation.

Sous-Commission 2. — Taches Solaires

Sub-Commission 2. — Sunspots

1. Que l'U. R. S. I. recommande que l'on continue l'effort entrepris pour établir les relations existantes entre les phénomènes solaires et la radio-transmission.

1. That the U. R. S. I. recommend continuation of the effort to correlate solar phenomena and radio transmission.

2. Que chaque Comité National intéressé constitue un Sous-Comité de Propagation, dans le but de réaliser dans le pays les autres recommandations et suggestions établies précédemment, et cela jusqu'où le Comité le jugera utile.

2. That each National Committee interested appoint a Sub-Committee on propagation for the purpose of carrying out in that country the remaining recommendations and suggestions previously set forth to whatever extent they see fit.

Sous-Commission 3. — Action Réciproque des Ondes

Sub-Commission 3. — Interaction of Radio Waves

Qu'une Sous-Commission composée de MM. Picault, H. L. Kirke et T. L. Eckersley, soit constituée pour préparer et organiser une expérience internationale sur l'influence réciproque des ondes; les rapports reçus seraient envoyés au Dr. van der Pol pour analyse et présentation des résultats.

That a Sub-Committee be formed, consisting of: Mr. Picault, Mr. H. L. Kirke, Mr. T. L. Eckersley, to devise and arrange an international experiment on the interaction of radio waves, the reports received to be sent to Dr. van der Pol for analysis and presentation of the results.

Sous-Commission 4. — Eclipses

Sub-Commission 4. — On Eclipses

1. Que l'on prépare d'avance pour les éclipses futures, des cartes des parcours optiques et crépusculaires.

2. Qu'à l'avenir, la concentration soit faite dans la région F_2, et que l'on apporte également une certaine attention à la région intermédiaire.

3. Que l'on s'efforce de standardiser la forme dans laquelle les résultats seront donnés.

4. Que le Comité Permanent de Mesures de l'Ionosphère dont la constitution est proposée, entreprenne l'organisation d'observations spéciales pendant les éclipses, ainsi que l'action à engager auprès des administrations pour obtenir l'appui pécuniaire nécessaire pour entreprendre ces observations.

1. That charts of the optical and corpusculars paths for future eclipses should be prepared in advance.

2. That concentration in future should be made on region F_2, while some attention should also be given to the intermediate region.

3. That attempts be made to standardise the form in which results are submitted.

4. That the proposed Permanent Committee on Ionospheric Observations should undertake the organisation of special observations during eclipses, including the making of application to Administrations for the financial grants necessary to carry out the work.

Proposition présentée par le Prof. E. V. Appleton

Proposed by Prof. E. V. Appleton

Etant donné la relation établie actuellement entre l'activité magnétique et les phénomènes anormaux de la radio et étant donné que des enregistrements continus des mesures de l'ionosphère sont faits dans diverses parties du monde, il est hautement désirable que les valeurs de l'activité magnétique pour des périodes inférieures à 24 heures soient mesurées par des observatoires magnétiques et communiquées aux autres chercheurs intéressés.

That, in view of the connection now established between magnetic activity and abnormal radio phenomena, and in view of the fact that continuous records of ionospheric measurements are now being made in different parts of the world, it is highly desirable that values of magnetic activity for shorter periods than 24 hours should be measured by magnetic observatories, and made available to other interested workers.

COMMISSION III

Sous-Commission 1. — Origine des Atmosphériques

Sub-Commission 1. — Origin of Atmospherics

1. La Sous-Commission estime qu'une connaissance approfondie de la structure des atmosphériques provenant d'orages ou d'autres sources serait d'une grande importance pour l'interprétation physique des atmosphériques; cette connaissance serait très utile en vue des progrès à réaliser et servirait également aux applications de la pratique.

1. The Sub-Commission is of the opinion that full knowledge of the structure of atmospherics originating from thunderstorms or from other sources would be of extreme value for their physical interpretation, and would therefore greatly advance science as well as serving pratical purposes.

2. La Sous-Commission estime que toutes les recherches sur le processus physique des décharges des éclairs par des méthodes autres que celles de la radio-électricité seraient utiles pour l'étude de la nature des atmosphériques.

2. The Sub-Commission is of opinion that all investigations on the physical processes in lightning discharges by methods other than radioelectric methods would be of value in the investigation of the nature of atmospherics.

3. La Sous-Commission recommande que l'on continue à développer autant que possible les enregistrements optique et photographique des déflagrations des éclairs, de façon à pouvoir fournir une base précise pour l'étude du rôle de l'éclair comme source d'atmosphériques.

3. The Sub-Commission recommends that optical and photographic recording of lightning flashes should be pursued and developed as much as possible, in such a way as to furnish a precise basis for the study of the role of lightning as a source of armospherics.

4. Les observations considérées dans la résolution 3, qui seraient orientées principalement en vue de l'étude des régions de nuages orageux intéressées par les décharges des éclairs,

4. The observations envisaged in resolution 3 which would be principally directed to the study of the regions of thunderclouds involved in lightning discharges and of the time-relations

devraient, dans l'esprit de la Sous-Commission, être considérablement amplifiées par l'organisation d'observations simultanées des variations du champ électrique.

5. La Sous-Commission estime que les observatoires magnétiques répandus dans le monde pourraient apporter une contribution importante aux recherches statistiques sur les orages, en analysant les enregistrements magnétiques montrant les effets des éclairs.

6. Il serait désirable que l'on installe en de nombreux points, des appareils pour l'enregistrement de la pente du potentiel ainsi que des appareils pour l'enregistrement des points de décharge, de façon à pouvoir comparer les variations du champ magnétique aux angles d'incidence des atmosphériques.

Pour de tels enregistrements, on conseille l'échelle de 5 mm. pour une minute.

7. La Sous-Commission estime que l'on devrait poursuivre les études relatives au problème des troubles électriques d'origine d'apparence extraterrestre et que l'on devrait commencer des observations sur une gamme étendue de fréquences, spécialement de hautes-fréquences, en un certain nombre d'endroits des deux hémisphères.

8. La Sous-Commission propose de constituer un Comité Permanent comprenant : MM. le Prof. Norinder (Président), R. A. Watson-Watt, Dr. B. F. J. Schonland, pour attirer l'attention des organismes intéressés sur le programme contenu dans les résolutions précédentes et présenter à la prochaine Assemblée Générale de l'Union, un rapport sur les travaux effectués dans l'intervalle.

of the elements of the discharge would, in the Sub-Commission's opinion, be greatly increased in value by simultaneous observations of changes in the electric field.

5. The Sub-Commission is of opinion that the magnetic observatories throughout the world can make important contributions to statistical researches on thunderstorms by the analysis of magnetic records showing the effects of lightning.

6. That it is desirable that apparatus for recording potential gradient and apparatus for recording point-discharge be installed at numerous places so that the changes in the electric field may be compared with the incidence of atmospherics.

A scale of 5 mm. to one minute is recommended for such records.

7. The Sub-Commission is of opinion that further studies of the problem of electrical disturbances of apparent extra-terrestrial origin should be made, and that observations should be made over an extended range of frequencies, especially higher frequencies, and at a number of places in both hemispheres.

8. That a Standing Committee be appointed consisting of : Prof. H. Norinder (President), Mr. R. A. Watson-Watt, Dr. B. F. J. Schonland. to draw the attention of interested bodies to the programme contained in the foregoing resolutions and to report at the next Congress of the Union on the work which has been done in the interval.

Sous-Commission 2. — Propagation des Atmosphériques

Sub-Commission 2. — Propagation of Atmospherics

La Sous-Commission ayant passé en revue la distribution dans le monde des stations où des recherches fondamentales sur les atmo-

The Sub-Commission, having reviewed the distribution throughout the world of the stations at which fundamental investigations on sphériques sont effectuées, recommande l'extension de ces recherches et principalement leur commencement en Afrique et dans l'Amérique du Sud.

atmospherics are now in progress, recommends the extension of such work and its initiation in Africa and South America as of especial importance.

Sous-Commission 3. — Mesures des Atmosphériques

Sub-Commission 3. — Measurements on Atmospherics

1. Que l'on adopte pour l'enregistrement des atmosphériques, approximativement, les fréquences de 12, 24, 27, 60, 90, 300, 1.500, 7.500 et 20.000 kc/s. La préférence serait donnée à 27 kc/s.

2. La Sous-Commission demande la constitution d'une Sous-Commission Permanente composée de : MM. le Comm. R. Bureau (Président), le Dr. J. Lugeon, R. A. Watson-Watt, et chargée d'organiser l'enregistrement des atmosphériques, de façon à pouvoir finalement déterminer le taux de production des perturbations électriques dans les diverses régions du globe, et ce, à tout moment.

1. That the series of frequencies of approximately 12, 24, 27, 60, 90, 300, 1.500, 7.500 and 20.000 kc/s. be adopted for the recording of atmospherics. Preference should be given to recording on 27 kc/s.

2. The Commission recommends that a Permanent Sub-Commission consisting of Comm. R. Bureau (President), Dr. J. Lugeon, Mr. R. A. Watson-Watt, be appointed to organise the recording of atmospherics in such a way that the rate of generation of electrical disturbance in all regions of the globe at all times may ultimately be determined.

Sous-Commission 4. — Radiogoniométrie des Atmosphériques

Sub-Commission 4. — Direction-Finding of Atmospherics

1. Considérant les résultats déjà obtenus par les enregistrements quotidiens par la méthode du secteur étroit, la Sous-Commission estime que l'organisation d'un réseau étendu, à larges mailles, de radiogoniomètres à secteur étroits, est pour le moment, un des moyens les plus rapides pour améliorer nos connaissances relatives aux sources des atmosphériques et pour permettre une étude plus serrée des relations existant entre ces sources et les phénomènes météorologiques.

La Sous-Commission recommande que :

a) cet enregistrement soit continué dans les stations où il est effectué actuellement et qu'il soit repris dans celles où il a été suspendu.

1. The Sub-Commission having considered the results already obtained in daily recording by the narrow-sector method, considers that the organisation of an extended network, of open mesh, of narrow-sector radiogoniometers is at the present moment one of the most rapid means for improving our knowledge of the principal sources of atmospherics and permitting a more profound study of the relations between these sources and meteorological phenomena.

The Sub-Commission recommends that :

(*a*) recording should be continued in the stations where it is now being carried out and should be resumed in those in which it has been suspended.

b) chaque fois que les circonstances le permettent, de nouvelles stations d'enregistrements soient créées, la fréquence de l'onde d'enregistrement étant d'environ 27 kc/s.

c) l'échange des résultats soit organisé en utilisant soit les services postaux, soit la radiotélégraphie.

2. La Sous-Commission estime que

a) les observations faites actuellement à l'aide de radiogoniomètres à rayons cathodiques ont une grande importance pour les études sur la nature et l'origine des atmosphériques, et que les observations de ce caractère devraient être effectuées à l'aide d'un réseau étendu à larges mailles.

b) les installations de ce genre en Allemagne et en Suède ainsi qu'en Afrique et en Amérique du Nord seraient d'une importance particulière.

c) des observations simultanées devraient être organisées chaque fois que la chose est possible.

3. La Sous-Commission recommande la création d'un Comité Permanent constitué par : M. R. A. Watson-Watt (Président), le Comm. R. Bureau, le Dr. J. Lugeon, le Prof. H. Norinder, le Dr. B. F. J. Schonland, le Dr. K. W. Wagner, le Dr. H. T. Friis; ce Comité aurait pour mission de réaliser les propositions relatives à la radiogoniométrie contenues dans les résolutions précédentes et de préparer un rapport à présenter à la prochaine Assemblée Générale de l'U. R. S. I.

(*b*) whenever circumstances permit new recording stations should be created, the frequency of the recording wave being about 27 kc/s.

(*c*) the exchange of results should be organised either by postal or by radiotelegraphic means.

2. The Sub-Commission is of opinion that

(*a*) the observations now being made by the aid of cathode-ray direction-finders are of great importance to studies on the nature and origin of atmospherics, and that observations of this character should be carried out by an extended network of open mesh.

(*b*) installations in Germany and Sweden and in Africa and North America would be of especial value.

(*c*) some simultaneous observations should, whenever possible, be arranged.

3. The Sub-Commission recommends that a Standing Committee be appointed consisting of: Mr. R. A. Watson-Watt (President), Comm. R. Bureau, Dr. J. Lugeon, Prof. H. Norinder, Dr. B. F. J. Schonland, Dr. K. W. Wagner, Dr. H. T. Friis, to give effect to the proposals for directional recording contained in the foregoing resolutions and to prepare a report for the next congress of the Union.

COMMISSION IV

Il est à souhaiter que les Comités Nationaux qui préparent des Ursigrammes les envoient par la poste au Secrétariat Général à Bruxelles, celui-ci transmettra mensuellement à tous les Comités Nationaux, la série complète d'Ursigrammes.

That it appears desirable to request each National Committee which prepare Ursigrams to send them by mail to the General Secretary at Brussels, who will then transit monthly to all the National Committees complete sets of the Ursigrams.

COMMISSION V

1. La Commission est désireuse de voir procéder à des recherches plus complètes sur le mécanisme des oscillations électriques aux ultra-hautes fréquences, à l'aide de tubes électroniques tels que les oscillateurs Barkhausen-Kurz, Pierret, etc.; elle demande au Prof. Mesny et au Dr. Wagner de préparer un rapport sur ce sujet pour la prochaine Assemblée Générale de l'U. R. S. I.

2. La Commission désire voir étudier la propagation des ondes ultra-courtes (celles en-dessous de 10 m. par exemple), une telle étude comprenant la détermination de l'effet de l'atmosphère. Elle demande au Dr. Dellinger et à Mr. T. L. Eckesley de préparer un rapport sur cette question.

3. La Commission désire voir pousser l'étude théorique et expérimentale des mouvements browniens des électrons dans les conducteurs et de l'effet de choc dans les tubes thermioniques. Elle demande à MM. Llewellyn, Moullin et au Dr. van der Pol de préparer un rapport sur ces sujets.

4. La Commission désire voir continuer l'étude des oscillations non-linéaires et demande au Dr. van der Pol de préparer un rapport sur cette question.

5. La Commission d'accord avec la Commission II, désire voir continuer les recherches sur la théorie de la propagation et de l'absorption dans l'atmosphère, ainsi que des conditions dans lesquelles la propagation obéit aux lois de l'optique géométrique et de celles de ces conditions pour lesquelles les lois générales de la théorie des ondes pourraient être appliquées. La Commission demande à M. Eckersley et au Prof. Manneback de préparer un rapport sur cette question.

1. The Commission desires the further investigation of the mechanism of generation of electrical oscillations of ultra high frequency, by means of electronic tubes, for example, Barkhausen-Kurz, Pierret oscillators, etc.; and asks Prof. Mesny and Dr. Wagner to prepare a report on the subject for the next meeting of the U. R. S. I.

2. The Commission desires the study of the propagation of ultra short waves, (i. e. below 10 m.) such study to include the determination of the effect of the atmosphere; and asks Dr. Dellinger and Mr. T. L. Eckersley to prepare a report on the subject.

3. The Commission desires the further theoretical and experimental study of the Brownians movements of electrons in conductors, and of the shot effect in thermionic tubes. The Commission asks Messrs. Llewellin, Moullin and Dr. van der Pol, to prepare a report on those subjects.

4. The Commission desires the further study of the theory of non-linear oscillations, and asks Dr. van der Pol to prepare a report on the subject.

5. The Commission jointly with Commission II, desires the further investigation of the theory of propagation and absorption of waves in the atmosphere, and of the conditions under which the propagation obeys the laws of geometrical optics and of those conditions under which the general laws of wave theory should be applied. The Commission asks Mr. T. L. Eckersley and Prof. Manneback to prepare a report on the subject.

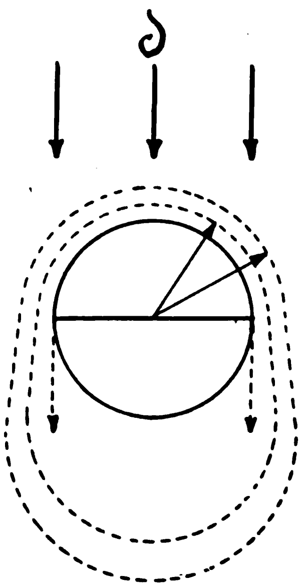
Résumés des Documents

Abstracts of Papers

No 1. — **Note sur l'intérêt de sondages continus de l'ionosphère par la méthode des radio-échos,** par M. A. Dauvillier. — (Texte Complet).

Le phénomène de la variation diurne de l'aurore, polaire et non polaire, recevrait une interprétation simple dans l'hypothèse d'une déformation de l'ionosphère par la pression de radiation solaire, causant une sorte de queue cométaire cylindrique creuse attachée à la Terre.

Il semble que l'enregistrement continu de la hauteur des hautes couches conductrices de l'ionosphère permettrait, en traçant un diagramme polaire statistique dans le plan équatorial (fig.) et dans divers parallèles, de déterminer la forme des ellipsoïdes réflecteurs et par suite de vérifier l'hypothèse ci-dessus. Cet enregistrement devrait, semble-t-il, être continu durant une année et être effectué simultanément dans plusieurs stations de latitudes différentes.



No 2. — **Rapport établi par le comité national français sur les renseignements que peuvent fournir les résultats du trafic, sur les phénomènes de propagation.**

A la session de Copenhague, l'Union de Radiotélégraphie Scientifique Internationale avait chargé le Comité National Français de concentrer les renseignements que pourraient lui fournir les administrations et compagnies privées françaises sur les résultats du trafic et de dépouiller ces renseignements pour en tirer toutes conséquences utiles sur la propagation.

Ce programme a pu être exécuté grâce à l'obligeance de l'Administration française des Télégraphes et de la Cie Générale de Télégraphie sans Fil.

Cette dernière Compagnie a fourni au Comité français des renseignements sur les fréquences utilisées pour les diverses transmissions depuis 1929.

L'état d'esprit qui a présidé à l'examen des résultats ainsi fournis était le suivant. Chercher si la variation qui s'est produite au voisinage de 1930 dans l'activité solaire a entraîné des variations dans le mode de propagation des diverses fréquences, variations qui auraient entraîné la nécessité de modifier la fréquence utilisée dans certaines conditions pour assurer un certain trafic.

Aucun résultat concluant n'a pu être tiré des renseignements fournis. Dans la majorité des cas, les changements de fréquence effectués sur une liaison donnée l'étaient pour des raisons complètement indépendantes des conditions de propagation (nécessité d'éviter un brouillage).

Toutefois, il importe de remarquer que tous ces résultats se rapportaient à une époque où se développaient les liaisons radioélectriques. On peut penser que dans les années qui vont suivre on se trouvera en présence d'une situation plus stable et qu'on pourra tirer des conséquences de résultats comme ceux que nous venons de mentionner plus haut.

En particulier, on pourra peut-être utiliser les renseignements fournis au Comité par l'Administration française des P. T. T. qui indiquerait chaque jour pour une liaison donnée la façon dont se comportent diverses fréquences.

Le Comité français pense qu'un représentant de l'Administration française des Postes et Télégraphes pourra peut-être donner lors de la prochaine réunion de l'U. R. S. I. quelques renseignements sur les premiers résultats obtenus.

L'Administration française des Postes et Télégraphes a communiqué également au Comité français les appréciations journalières de ses agents sur les diverses liaisons. Ces appréciations sont caractérisées par une note de 0 à 5 et par des remarques sur les incidents qui se sont produits (brouillages, signal arrivant dans deux directions.)

Là encore, il a été constaté qu'aucune conclusion scientifique ne pourrait être déduite des résultats fournis, les appréciations étant trop influencées par des considérations étrangères au mécanisme de la propagation.

Néanmoins cette collaboration entre le Comité français et l'Administration des Télégraphes a eu quelques résultats fort intéressants.

C'est ainsi que l'attention de certains membres du comité a été attirée sur ce fait qu'à certaines heures on recevait de certains postes un signal double. Ceci a permis d'organiser des expériences dont on a déduit la vitesse apparente de propagation,.

L'examen attentif des résultats communiqués a montré également que la grande pluie d'étoiles filantes avait été sans effet sur la propagation des ondes.

En résumé le Comité français estime que la collaboration qu'ont bien voulu lui apporter l'Administration française des Postes et Télégraphes et la Compagnie Générale de Télégraphie sans fil (¹), sans avoir fourni, loin de là, les résultats qu'on pouvait en espérer a été plutôt favorable à son activité.

Du reste il pense également que dans un laps de temps plus ou moins éloigné on pourra arriver à tirer parti de l'ensemble des observations faites par ces Administrations sur la façon dont les diverses fréquences se comportent suivant les heures du jour et suivant les saisons.

13 mars 1934.

Nº 3. — **Rapport pour la commission de propagation des ondes,** par le Prof. Dr. Jhr. J. G. ELIAS.

Ce rapport est un résumé de différentes études concernant la propagation des ondes et dont voici les titres :

A. — THEORIE

1. Calcul de l'ionisation de l'atmosphère. *Tijdschv. v. h. Nederl. Radiogenootschap,* 2, p. 1, 1923; 3, p. 1, 1926. — *Elektr. Nachr. Techn.,* 2, p. 351, 1925. — *Zeitschr. f. Hochfrequenztechn.,* 27, p. 66, 1926.

2. Calcul de la réflexion par un milieu ayant une conductibité et une constante diélectrique données par des fonctions exponentielles. *Elektr. Nach. Techn.,* 8, p. 4, 1931.

3. Application du calcul du coefficient de réflexion au cas de l'ionisation de l'atmosphère. *Tijdschr. v. h. Nederl. Radiogenootschap,* 5, p. 19, 1930. — *Proceed. Institut of Radio Engineers,* 19, p. 891, 1931.

B. — EXPERIENCES

1. Mesure de la réflexion en faisant usage des interférences de la radiation directe et des rayons réfléchis. *Tijdschr. v. h. Nederl. Radiogenootschap,* 5, p. 133, 1932. — *Elektr. Nachr. Techn.,* 10, p. 1, 1933.

(¹) G. MAIRE, *Onde Electrique,* août-septembre 1934.

2. Mesure de la hauteur de réflexion et conclusions concernant le coefficient de recombinaison. *Tijdschr. v. h. Nederl. Radiogenootschap.*, 6, p. 53, 1933. — *Elektr. Nachr. Techn.*, 10, p. 400, 1933.

N° 4.— **Report on the work organised on behalf of Commission I since the session in Copenhagen 1931,** Dr. E. H. RAYNER, President of the Commission. — (Full text).

The Commission will, I know, wish me to put on record their great regret at the loss which we have experienced in the death of Dr. D. W. Dye. He had been president of the Commission since the meeting in Washington in 1927; and his reports and his mastery of the technique of radio and other branches of electrical measurement made him an admirable president. To me, who had been his colleague and who had been in a position to appreciate his ability and achievements for more than 20 years, his loss has given the impression of a break in the progress of measurement and instruments which he had done much to develop.

At Teddington we are extending the work which Dr. Dye commenced; and I have little doubt that greater certainty and precision will be achieved, and that new applications will be found for methods and equipment which he had done much to develop, primarily for radio purposes.

I recognise that it is largely due to the work of Dr. Dye and to the position which the National Physical Laboratory has attained, that I have been requested to be president of the Commission. This service I have been glad to undertake as a recognition of his work and of the appreciation of it among the members of the Union.

SUBJECTS CONSIDERED. — The subjects dealt with are the development and intercomparison of standards of radio frequency and the measurement of the intensity of a radiating electric field.

MEASUREMENT OF FREQUENCY. — The most important subject which has been under consideration since the last meeting at Copenhagen, has been further developments in the technique of the maintenance of constancy of frequency, and in the international comparisons of standards of frequency.

The maintenance of standards of radio frequency is generally regarded as a duty of a national laboratory, in some cases as part of the work of a general physical laboratory, in other cases of a laboratory devoted to radio work.

The verification of the value of a frequency in absolute measure requires a knowledge of the total number of oscillations in a period of time known with sufficient exactness. Periods of time determined by the performance of pendulum cloks are becoming insufficiently precise, and the verification by daily time signals is also becoming insufficiently accurate for the most perfect types of oscillators now available, unless periods of many days are used, by which the effect of errors due to variation of signals from day to day may be reduced. This has been established in a notable publication by A. Scheibe and Adelsberger, of the Physikalisch Technische Reichsanstalt, Berlin (¹), in which it is shown that a quartz oscillator can have a stability of 1 part in 200 million for periods of few hours and 1 part in 100 million for periods of several days. One part in 100 million corresponds to 0.001 second a day, a steadiness which few cloks can attain, so that a crystal oscillator promises to provide new possibilities as an accurate divider of time. The fundamental observations on which time measurement depends are those of stellar transits, and it is necessary to take observations at many days interval to attain an accuracy necessary to verify the performance of the most perfect oscillators.

Scheibe and Adelsberger have recently published another paper giving technical details of the

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(¹) *Physical Z. S.*, 33, 835, 1932.

latest developments of their quartz oscillator equipment. The fundamental frequency is 60.000 cycles per second. Frequency dividing circuits and a synchronous motor are used for obtaining time signals comparable with 1 second of time (¹).

A notable paper, describing the researches of Dr. Dye on the mode of deformation of the surfaces of quartz crystals when resonating to the many different frequencies to which they will often respond, has been published by the Royal Society (²). Another paper on the work of Dr. Dye on the measurement of frequency has also been published (³).

A lecture on Dr. Dye's work on these subjects given to the Institution of Electrical Engineers, by Dr. E. H. Rayner, has also been published (⁴).

Use of a Frequency of Reference for International Comparisons. — For the purpose of making international comparisons of frequency, portable apparatus is no longer used. Comparisons are made directly between the standard apparatus in different countries by means of a frequency of reference. A frequency of reference for this purpose must be very steady. It may be a radio frequency or an audio frequency.

Use of Radio Frequency of Reference for International Comparisons. — Since the last meeting at Copenhagen the Bureau of Standards has continued the weekly emission of a frequency of reference of 5.000.000 cycles per second. The power has been increased. The nominal accuracy is within 1 cycle per second. Before the power was increased it was impraticable to make use of the emission in Europe generally, though it could frequently be done at Teddington with some difficulty. Since the power was increased there has been no difficulty in making satisfactory measurements at Teddington, and on every occasion it has been practicable to make comparisons with an accuracy of about 1 part in 100 millions. It will be of interest to learn what use can now be made of this emission in other countries.

On one occasion, March 14th, 1934, which will be referred to later, the value was found to be about 0.6 parts in 10 millions greater than the nominal value on about 5,000,000.3 cycles per second.

Use of a Modulation Frequency as a Frequency of Reference. — The use of a modulation frequency as a frequency of reference has certain advantages. There is a wide range of values to choose from, whereas a reference emission of a radio frequency is practically restricted to one fixed value, depending upon the design of the antenna and other equipment of the transmitting station. The value chosen for the modulation frequency can be decided by the general convenience of those making use of it.

There is a large number of organisations which have equipment depending on a basic frequency of 1,000 cycles per second, governing multivibrator equipments for obtaining higher values; so that a frequency of 1,000 is a suitable one for a reference frequency. It is one which is also very convenient for telephonic transmission, so that it can be generated at a distance from the radio station emitting it. Any convenient radio station can be used; and, if desired, two can be used simultaneously. There is no necessity for ensuring unusual stability or accuracy of the carrier frequency.

Emissions of this type have been made with the cooperation of the British Broadcasting Corporation, which has been most helpful in giving this international service. In the most recent of these the modulation has been generated at the National Physical Laboratory and sent by telephone wire to the radio station. On two of the last three occasions, June 29th-30th, 1932, and December 20th-21st, 1932, a fork of 1,000 c/s was used as the frequency generator, and the emission was made from Daventry on a carrier frequency of 193 kc/s.

(¹) *H. F. Tech. u. El. Ak.*, 43, 37, 1934.
(²) *Proc. Roy. Soc. A.*, vol. 138, 1, 1934.
(³) *Proc. Roy. Soc. A.*, vol. 143, 285, 1934.
(⁴) *J. I. E. E.*, vol. 72, 519, 1933.

EMISSION OF JUNE 29TH-30TH, 1932. — A letter, dated 18th June, 1932, was circulated announcing this emission in the form of a modulation frequency of 1,000 c/s, which was to be generated at Teddington, and emitted by the Daventry station of the British Broadcasting Corporation on a carrier wave of 193 kc/s. At the end of the period a small change of the modulation frequency was made by alteration of a condenser in the circuit of the valve driving the fork, to enable observers to determine whether the local frequency was higher or lower than that emitted.

The programme was as follows :

2355. Announcements.
2400-0130. Modulation 1000 c/s.
0130-0145. Modulation changed about 2 parts in a million.
0145. Announcements.

The report dated 16th September, 1932, gave the following results where absolute values could be ascribed to the frequency :

		Maximum Variation Parts in a Million
National Physical Laboratory	1000.0001 ± 0.0002	
Physikalisch Technische Reichsanstalt Berlin	1000.0002	0.3
Laboratoire National de Radioélectricité, Paris	1000.0001	0.3
Institut Radiotechniczny, Warsaw	999.9997	0.4
Post Office, Dollis Hill, England	1000.0001	0.2
Royal Aircraft Establishment, England	1000.0000	0.06

The emission was well received in Rome where the local oscillator, a fork, was calibrated, and also at other places which were not yet provided with primary oscillators. The conclusions were:

(1) Emissions made after midnight are for the most part received sufficiently well in European countries for accurate measurements to be made.

(2) Measurements may be made with an accuracy of better than 1 part in a million with the use of simple apparatus.

(3) A good reference standard and a slightly more elaborate apparatus enable a comparison to be made with an accuracy of 1 part in 10 millions.

(4) It appears probable that sufficiently good frequency standards could be compared by this method with an accuracy of 1 part in 100 millions.

The emission of June 29th-30th was one of the first attempts at an international comparison, and want of experience and knowledge concerning the most suitable methods of reception prevented some receiving stations making full use of it.

A second emission was arranged for December 20th-21st, 1932, according to a programme dated December 8th, and a letter giving an account of previous experience and some suggestions was circulated, dated December 9th. Owing to certain stations continuing in operation until 0130, the emission commenced an hour later than that of the previous one. The programme was similar.

EMISSION OF DECEMBER 20TH-21ST, 1932.

0155. Announcements.
0200-0330. Modulation 1000 c/s.
0330-0345. Modulation changed about 2.5 parts in a million.
0345-0355. Modulation restored to the original value.
0355. Announcements.

Several organisations were able to calibrate their local oscillators, and the following are results where absolute values of the local frequency can be determined :

National Physical Laboratory, Teddington	999.9999
Physikalisch Technische Reichsanstalt, Berlin	999.9998
Institut Radiotechniczny, Warsaw	999.9999
Brussels	999.999
Post Office, Dollis Hill, England	1000.0004
Royal Aircraft Establishment, England	999.9999

The general results show that when there is apparatus available for the determination of the local frequency in absolute measure agreement to 1 part in 10 million may be expected. The weak link in the chain has become the error in the absolute determination of time, depending upon transit observations and clocks; and there can be little doubt that oscillators devised primarily for radio work promise to have valuable applications in this field.

The stability and precision of oscillation generators suggest that these properties may have valuable applications in the study of the physics of radio propagation, which has been confirmed by some of the results obtained on the occasion of the emission on March 14th, 1934.

Emission of March 14th, 1934. — The third emission was made on March 13th-14th, 1934. The modulation frequency of 1,000 cycles per second of the principal emission from 0200 to 0330 was generated by a quartz ring oscillator of the type devised by Dr. Dye. The main emission was supplemented by subsidiary emissions, one of 15 minutes before and the other for 10 minutes after the main emission. They were generated by a fork and the frequency had a value about 2 parts in a million less than that of the main emission. These subsidiary emissions were for the purpose of assisting the receiving stations to determine whether their local frequency was greater or less than the main frequency.

The quartz ring of about 87 mm. mean diameter has a frequency for radial oscillation of 20,000 cycles a second. This frequency is automatically divided in one stage so as to produce a frequency of one-twentieth of its value, nominally 1,000 cycles per second; and this frequency was used to modulate the radio frequency. The actual value ascribed to it at the time by the National Physical Laboratory was 1000.0003 cycles per second. The carrier frequency of Daventry was 200 kc/s, having been changed from 193 kc/s early in 1934.

The British Broadcasting Corporation kindly offreed to use another station simultaneously, since it might prove more effective for some receiving areas. Advantage was taken of this suggestion. It promised to provide in addition an opportunity for acquiring information of a physical character. As a result of enquiries from possible observers the London Regional Station, 877 kc/s, was chosen. Suggestions for physical observations were circulated, dated 2nd March 1934, including the use of a cathode ray oscillograph operated by the modulation frequency as received by the two carrier waves simultaneously.

Result of Frequency Measurements, March 14th, 1934.

The programme was as follows:

0130-0145. Announcements from London in English, French and German, that the preliminary frequency would be 999.9984 p/s and that the main frequency would be 1000.0003 p/s.
0145-0200. Preliminary emission 999.9984 p/s.
0200-0330. Main emission 1000.0003.
0330-0340. Final emission 999.9986.
0340-0400. Announcements repeating the values of the preliminary and main emissions and adding the value of the third.

The reports which were received later showed that the agreement between the establishments which are equipped with apparatus for the measurement of frequency in absolute measure was very satisfactory. The values assigned to the frequency by Teddington (National Physical Laboratory), Paris (Laboratoire National de Radioélectricité), Berlin (Physikalisch Technische Reichsanstalt) and Brussels (Union Internationale de Radiodiffusion) were identical to the 10 millionth figure with the value 1000.0003, announced at the time of the emission. (If an additional significant figure had been given by the National Physical Laboratory, the value would have been 1000.00031).

France. — The report from Paris gave a value of 1000.0003 using Daventry, as a result of 60 measurements with a maximum dispersion of ± 0.0004.

Germany. — The Physikalisch Technische Reichsanstalt, Berlin, gave a value of 1000. 00030 based on a value of 998.80512 of the local oscillator. The time was divided into 27 periods of about 3 minutes each, the average frequency for each period being recorded. London was used for about an hour and Daventry for half an hour. The unsteadiness of the local beat frequency was about 3 times as great with London as with Daventry, a result which corresponds with the physical observations.

Belgium. — At Brussels the frequency was found to have a value of 1000.0003 using Daventry. A phonic motor was driven at 1000 c/s by the modulation frequency. Owing to the method of comparison used the probable error ± 0.00015 is somewhat larger than in other establishments, and it is proposed to increase the accuracy of comparison by simple methods. The results show, however, that the synchronous motor kept in step with the modulation frequency, probably without missing one cycle in the period of 5½ millions cycles of the emission. The effect of an error of one cycle would have altered the value 1000.0003 by one or two units in the last significant figure. A warning had been circulated concerning this method of measurement, since an atmospheric disturbance might have given rise to an error due to temporary failure of synchronisation. Experience showed that on this occasion no such trouble occured over the distance Daventry-Brussels, 440 km, using a carrier frequency of 200 kc/s.

Holland. — The value found at the National Radio Laboratory of Holland was 1000.0002, a value 0.0001 less than 1000.0003 mentioned previously. The value, however, was subject to possible alteration when the correction to time signals became available. The method used was to generate the 10th harmonic of the modulation frequency and to compare it with a local standard of 10 kc/s.

Sweden. — The Radio Department of the Board of Telegraphs were able to calibrate their local standard, a fork of 1000 p/s. They were also able to make a comparison with the standardising frequency of the Bureau of Standards, Washington, immediately after the emission from the National Physical Laboratory. Two values of the frequency of their fork were obtained; one on the assumption that the frequency from the National Physical Laboratory was 1000.0003, and the other that the frequency from the Bureau of Standards was 5,000,000. The two values were identical at 1000.1235.

Denmark. — Measurements were made in Denmark. During the first period the interval for one beat was 123 seconds, so that the local frequency was 0.0081 above or below 999.9984. During the second period the interval for 1 beat was 160 seconds, the frequency being 0.0062 above or below 1000.0003. The values indicate that the local frequency is higher than the modulation frequency; the value deduced from each period being 1000.0065.

Poland. — The measurements at Warsaw were not in such good agreement as on a previous occasion, the local oscillator showed a slow change and indicated that the modulation frequency was about 1 part in a million less than the value 1000.0003.

Italy. — The standard apparatus in Rome was being reconstructed, and the emission was used to calibrate a secondary standard.

Czekoslovakia. — The emission was used to calibrate the local apparatus which was recently installed. The accuracy of measurement was 0.2 in a million and agreed with the Rugby time signals. The Daventry signals were too much disturbed by atmospherics, for measurements to be made. London was much better; an anti-fading device was used. The use of two carrier frequencies was found to facilitate the measurements.

Russia. — The emission from Daventry was received well in Moscow, and it was found possible to investigate the effect on the change of frequency of the local oscillator, a fork, by alteration of driving conditions. The value found for the main emission was 999.9998.

America. — No reception was practicable in America. Atmospheric disturbances were reported to be prevalent at the Bureau of Standards. The regular standardising emission from the Bureau of Standards, which was emitted immediately after the European measurements, was received satisfactorily at Teddington and Stockholm.

EMISSION FROM THE BUREAU OF STANDARDS, WASHINGTON. — The frequency of reference emitted by the Bureau of Standards was measured at Teddington during the period 0400 to 0500 immediately after the completion of the international reference emission of March 14th. The average value assigned to the frequency by the National Physical Laboratory was 5,000,000.3 c/s. About 130 measurements were made of the beat frequency at the 5,000kc/s level. The same reference standard of 20 kc/s was used at Teddington, as had been used to produce the modulation for the emission from Daventry and London from 0200 to 0330.

SUMMARY. — The following is a summary of the principal results obtained on the occasion of the emission of March 14th 1934. Emission of 1.000 c/s from 0200 to 0330 from Daventry and London Regional. Modulation produced at the N. P. L. from a quartz ring oscillator of 20.000 c/s divided automatically down to 1000 c/s.

Values ascribed to the Modulation Frequency.

National Physical Laboratory ..	1000.00031
Berlin, P. T. R.	1000.00030
Paris Lab. Nat. Rad.	1000.0003
Brussels Broadcasting Union.....	1000.0003
Holland	1000.0002

Czekoslovakia, local oscillator calibrated, agreed with value from Rugby. Time signals to 0.2 in a million. Calibrations of local oscillators made in Denmark, Italy, Russia.

Stockholm, Frequency of local oscillator 1000.1235 (Assuming N. P. L. value 1000.0003).

Stockholm, Frequency of local oscillator 1000.1235 (Assuming B. of S. value 5000.000).

B. of S. (Washington) Emission of 5000.000 c/s. Value ascribed at N. P. L. 5000.000.3 c/s.

USE OF TWO CARRIER FREQUENCIES MODULATED BY THE SAME FREQUENCY SIMULTANEOUSLY. — The modulation of two stations simultaneously on March 14th afforded an opportunity for observations of a physical character. Suggestions that a cathode ray oscillograph might be used to record the two modulations simultaneously were made in a letter circulated on March 2nd.

Owing to the difference in lenght of telephone line and to the separation of the stations (London Regional, 877 kc/s; Daventry 200 kc/s) which was about 90 kilometres, the figure at any receiving station described by the cathode ray actuated by the two modulation frequencies would be in general an ellipse. There would be in addition an effect due to difference in, type of radio path of the two carrier frequencies.

Dublin. — Records were made of the cathode ray diagram every minute for 1½ hours (London, vertical — Daventry, horizontal). Two similar commercial receivers were used. The form of the diagram frequently changed with great rapidity, and the drawings only suggested predominant types. The commonest shape was an ellipse with a major axis about twice the size of the minor axis. The ellipse varied between a circle and a straight line, the latter being sometimes inclined, and becoming horizontal when the London station was very weak. Under such conditions a figure of eight diagram seemed to be produced, but this may possibly have been associated with the want of sensitivity of oscillograph in the region of zero amplitude. Measurements were also made at intervals of a minute of the horizontal (Daventry) and the vertical (London) amplitudes of the displacement of the cathode beam. These indicated that the Daventry amplitude was much steadier than that of London, though the record shows a ratio of about 2 to 1 between the maximum and minimum during the period of 1 ½ hours, London being of the order of 20 to 1. No measurements of frequency were made.

Paris. — Cathode ray observations were also made in Paris (London, vertical; Daventry, horizontal), observations being made generally every minute and sometimes every 10 seconds. An elliptical form was common, the intensity of Daventry being less variable than that of London. When the amplitudes were adjusted to equality the ellipse was usually about twice as long as wide, corresponding to a phase angle of 50° to 60°. Sometimes it changed to a straight line at an angle from 30° to 80° with the horizontal. Sometimes it became circular. At some periods changes of form were slow, and at others very rapid. On these occasions indications of frequency doubling was quite distinct, figures of 8 being formed at various inclinations, and sometimes with a considerable difference in the sizes of the two loops. At various times the figures are described as « brouillée », too indistinct and variable to be reproducible. Rapid variations and rapid rotation of the figures was noted for considerable periods, and at other times a relatively stable form occured. On the whole the period from 0145 to 0250 was less disturbed than after 0250, which seems to have been the case in Dublin. A short period stability was reported for two minutes at 0320.

Berlin. — In Berlin the unsteadiness of the modulation frequency was much more marked from the London station than from Daventry, and observations with a cathode ray oscillograph showed that the fading from London was much more pronounced, and that when the London station faded nearly to zero the phase of the beat frequency between it an the local standard might change up to 180°, rendering frequency measurements impracticable at such times.

Rome. — Similar cathode ray observations were made in Rome. It was found, however, that the amount of amplification required resulted in the production of appreciable distortion in the voltage applied to the oscillograph, so that the results were not sufficiently accurate to provide any definite conclusions. The experience indicated the procedure to follow to effect improvements on future occasions.

Cambridge. — Observations were made at Cambridge by a cathode ray oscillograph on the modulations received from Daventry and London. The diagram described by the ray was nearly circular, indicating a phase difference of approximately 90°. Owing to the proximity of the two stations there was no appreciable change in the figure described. There was, however, a rapid doubling or even trebling of the vertical parts of the circle, indicating a slight variability in the amplitude from Daventry. London produced a vertical and Daventry a horizontal displacement.

It is not certain whether the effect is of an instrumental character or whether it is a definite physical phenomenon. It changed to the horizontal part of the figure when Daventry and London were interchanged by rotating the frame aerials used for reception.

DROITWICH RADIO STATION. — It may be noted that the now Droitwich Station of the B. B. C., about 65 km west of Daventry, is expected to be in operation before the end of the year. It will take the place of Daventry as regards emissions at 200 kc/s. It will have about three times the power.

GENERAL RESULT. — The general result is that agreement between organisations in several countries to a few parts in 100 millions can be attained, when absolute methods are available for the determination of the value of the frequency of the local standard. The accuracy is limited by small errors in time measurement, depending upon clocks and astronomical observations, and upon the errors due to the process of determining the number of oscillations in the time interval.

The irregularities in the absolute measurement of time and its distribution necessitate periods of several days to be used in order to reduce the errors to a sufficiently low value for verifying the performance of the best oscillators. It is also essential that great stability of frequency of oscillators shall be attained for lengthy periods when measurements to 1 part in 10 millions or 1 part in 100 millions are required.

USE OF A MODULATION FREQUENCY. — The intercomparison of apparatus used for standards of radio frequency can be very successfully carried out by emitting a frequency of reference of a convenient value as a modulation of a carrier wave. In a time interval of about 90 minutes an accuracy of 1 part in ten million can be attained, and there is good evidence that a higher accuracy is obtainable. At a distance from the sending station the effect of the radio path is to give rise to slight frequency modulation. In the period of 90 minutes the total effect of this has not prevented an accuracy of 1 in ten millions being attained, if fading is not serious. This subject is referred to later.

The modulation will operate a phonic motor satisfactorily at a distance of 440 km., using a carrier frequency of 200 kilocycles a second.

Any convenient modulation frequency can be used and the carrier frequency need not have great constancy.

USE OF A RADIO FREQUENCY. — If intercomparison is carried out by a radio frequency and the measurements are made in a similar manner, by beats, the same proportional accuracy of comparison may be obtained in a much shorter time. An important requirement is that the two frequencies must be nearly equal. A beat frequency of 2 to 4 per second has been found suitable when making comparisons of the emission of 5,000,000 cycles per second of the Bureau of Standards at Teddington. If the beat frequency is longer than this it may become indefinite on account of fading. If it is shorter it is difficult to count.

Experience shows that, by choosing suitable periods of a few seconds in which to count the beats, satisfactory results can be obtained; while fading and other irregularities make impracticable longer periods for counting or recording the beat frequency. It has been found practicable to make about 50 measurements during an observational period under these conditions, agreeing among themselves within 1 part in 100 millions.

The use of a radio frequency limits the frequency to one value, depending of the equipment of the sending station, and the standard equipment has to be so arranged as to control very closely the emitted frequency either automatically or by hand.

INFLUENCE OF INTERVENING MEDIUM ON THE ACCURACY AVAILABLE. — The effect of the intervening medium, however, must be considered when the highest accuracy available is required. A modulation frequency, of constant value when emitted, may acquire unsteadiness on the way to the receiving station and over the range of frequency of 200 to 900 kc/s the unsteadiness will increase with distance and with increase of the frequency of the carrier wave. Unsteadiness is associated with fading; and the phase alterations indicate considerable and rapid changes of effective path between transmitter and receiver.

The results show that using the carrier frequency from London the modulation frequency was at times subject to unsteadiness and fading to such an extent that measurements were untrustworthy, except at intervals of relative steadiness. Rapid changes of the phase difference of the modulation frequency received from London and Daventry were observed in Dublin, Paris, Berlin and Rome; and, when using the London emission at Berlin, it was not possible at these times to correlate the instants of beats of the modulation wave with the local oscillator before and after such fading periods. A change of phase of the beat frequency up to half a period was occasionally noted.

The experience of March 14th shows that taking into account the method and distances of observing stations, it is necessary, when the highest accuracy is required, to use a carrier frequency which is sufficiently low to be free from serious fading, and which is more likely to follow the same path for a period of an hour or more than a carrier frequency of higher value which is liable to appreciable fading or unsteadiness.

Though the path of a low carrier frequency is less variable, and the modulation may be free from detectable unsteadiness and serious fading, there is no certainty that its path may not change slowly and measurably during the period of measurement. This would result in a difference between the number of modulations emitted and those receved. A change of path of 10 kilometres between the beginning and end of an emission, would have the effect of the change of 1/30th of a cycle of a modulation of 1,000 c/s. This is quite a measurable quantity, and in a period of 90 minutes, 5,400,000 oscillations, the error caused by it would be 1 part in 160 millions, a quantity which is becoming significant.

General Conclusions. — The results recorded in this report indicate a notable technical achievement. The constancy and accuracy of apparatus in use for the measurement of radio frequency has reached a standard which would hardly have been thought possible a few years ago. The constancy of frequency of oscillators depending upon mass and stiffness compares favourably with that of pendulums. A constancy of operation corresponding to less than a second in a year is now available, and only requires an adequate constancy of temperature, pressure, power supply, etc. to make it effective.

It is interesting to note that the frequency of the oscillators which have been successfully developed is of a different order from that of the common pendulum, being usually 1000 to 100,000 times as great.

The perfection of stiffness oscillators as time-dividing instruments cannot fail to make them of value for other purpose such as astronomy and geodesy. The possibilities of frequency multiplication and division afford an elasticity of utilisation of a unique character. From any suitable primary frequency a great range of secondary frequencies can be developed automatically, and any one of them can be chosen to suit the type of phenomenon which is being studied.

For instance from a frequency of 100,000 exact submultiples such as 10,000, 5,000, 1,000, 100, 10 and 1 or intermediate values, can be obtained as desired.

A number of such frequencies can be obtained simultaneously. They can be obtained intermittently for a few seconds every minute or hour or day, without losing continuity due to their omission in the intervals. Several different frequencies can be provided for short periods every minute in succession and repeated from minute to minute.

Finally a wide range of them can be generated at any suitable establishment and can be transmitted by telephone wire or by radio. Any number of observers can make use of the same time service simultaneously.

These developments indicate that there are great possibilities of adapting methods and apparatus devised for radio purposes to other branches of science. It is hoped that the work and influence of the Union will be of material value in assisting progress in these directions

The development of the use of oscillators having frequencies of a small fraction of a second promises to lead to the greater use of oscillographs for delineating and recording the time of events. The cathode ray type provides without difficulty a resolving power of a fraction of a microsecond.

Acknowledgments. — Finally I wish on behalf of the Commission to thank those in many countries who have freely given their services and have assisted in making the observations which have been described. Without this friendly international cooperation the work could not have been done.

We are specially indebted to the British Broadcasting Corporation which has willingly offered its services for assisting researches carried out on behalf of the Union.

PROPOSALS FOR DISCUSSION. — At the meeting of the Commission in September it is proposed to discuss what further work on these lines is desirable, including the assistance which radio methods can give to other branches of science.

The utilisation of « centimetre » waves, i. e., of a wave length from 10 to 100 cms., will be facilitated if they can be produced with great stability of frequency and accuracy. This subject is also proposed for discussion.

I shall be glad to receive any information or suggestions on these or other subjects which may be useful for the work of the Commission.

MEASUREMENT OF THE INTENSITY OF RADIATION. — In accordance with the resolution of the session at Copenhagen, it was decided that information should be collected on the measurement of the intensity of electric radiation. The late Dr. Dye offered the services of Commission I for the purpose. Since his death a questionnaire has been circulated by Great Britain, a copy of which is given as an appendix to this report. A satisfactory number of replies has been received. The analysis of these is in progress, and a report will be circulated in due course. A bibliography was circulated with the questionnaire. This will be amplified and reproduced in the report, and is not reproduced here.

June 6th 1934.

Questionnaires on the Measurement of Field Intensity

At the general meeting of Commission I of the U. R. S. I. Assembly in Copenhagen in 1931, it was agreed that information should be collected relating to methods of measuring the intensity of electric fields at radio frequencies. The late Dr. D. W. Dye, President of Commission I, undertook, on behalf of the British National Committee, the collection of this information and the preparation of a summarising report on the subject. It is now requested that you will be good enough to assist the British National Committee in this undertaking by supplying the information which you have available, either in the form of answers to the questions contained in the following questionnaire or as a separate memorandum, or, preferably, in both forms. Replies should be sent to Mr. R. A. Watson Watt, The National Physical Laboratory, Teddington, Middlesex, England, and it would facilitate the work of the Committe if answers could be made to reach him on December 15th, 1933, or earlier if practicable.

Name :

Address :

Representing :

1. What do you understand by the statement that the field intensity at a point X due to a transmitter at Y is Z volts per metre ? Is your use or interpretation of the term normally applicable only to the vertical or horizontal component of the electric field?

2. Have you previously engaged or do you regularly engage in the measurement of radio field intensity ? If so, for what general purposes ?

3. Do your measurement of field intensity refer to the value at the earth's surface or at some height above it ? If the latter at what height ?

4. What ranges of frequency and of field intensity are covered by the apparatus you employ ? Over what distances between transmitter and receiver are the measurements normally conducted?

5. On what types of emission does your apparatus work (*a*) unmodulated continuous wave ; (*b*) « keyed » continuous wave ; (*c*) telephony ; (*d*) « keyed » interrupted continuous wave or spark ; (*e*) any other type ?

6. Has a description of the method you use been published ? If so, give reference and, if possible, attach a reprint.— If not, please attach a description, with diagrams and photographs, if available, to this document.

7. Does the method employ a closed loop or an open aerial for receving the electric force to be measured ?

8. Have you made any comparison between measurements obtained on the same signal with closed loop and open aerial respectively ? If so, please give full details of the results obtained, including the effect of frames or aerials of different sizes.

9. How is the electric field intensity calculated from the electromotive force induced in the particular aerial system used ?

10. What order of amplification is employed in the measuring apparatus (*a*) at the signal frequency and (*b*) at any other frequencies ?

11. What form of indication is used in the apparatus and to what accuracy can this be read ?

12. How is the calibration of the whole apparatus carried out to ascertain the meaning of the indications ? What type of attenuation is employed and how is its calibration verified for the frequency used ?

13. What precautions are taken to screen the component parts of the apparatus as, for example, to avoid « antenna » effect with closed loops ?

14. What is considered to be the overall accuracy of the apparatus ? Upon what information is the answer based ?

15. What accuracy do you consider to be necessary in order to meet the objective in your investigation ?

16. Have any comparative checks been carried out at any time with the other methods of measuring field intensity ? If so, give details.

17. Are you acquainted with any apparatus or method of measuring field intensity which you know to be superior to that which you are using? Give details.

18. Is your apparatus suitable for use (*a*) in a fixed position on land; (*b*) in a mobile position on land; (*c*) at sea; (*d*) in aircraft ?

19. Has the effect of the proximity of the earth on the indications of the apparatus been investigated or considered ? If so, what was the result ?

20. (A skeleton list of publisehd papers on the subject is attached. Please suggest additions or corrections to,or deletions from, this list so that an authoritative list may be appended to the British Committee's report). This will be circulated later.

21. If you have any further information or comments on this subject which you think would be of use or interest, please add them to your reply. In particular, please suggest any supplementary questions which should be added to the present questionnaire.

Nº 5. — **Report on radio wave observations made at Angmagssalik by the Dutch expedition during the International Polar Year 1932-1933** by J. A. de Bruine.

A. — *Observations on the Ionisation of the Upper Atmosphere.* — A wavelength of 75 meters was used to measure the effective height of the ionised regions, and the following results were gained :

(*a*) There are two intervals of main reflections: from 100-200 km and from 300-450 km ; reflections at an effective height below 100 km were never observed with surety.

(*b*) In spring and in summer the number of reflections apart from the height increases.

(*c*) Reflections at an effective height below 200 km occur chiefly by night.

(*d*) The mean distribution of the reflections over the hours of a day shows a distinct maximum at about 20h local mean time.

(*e*) The mean distribution of the Magnetic Activity shows a distinct maximum at about the same time.

From the continuous records of the effective height the following conclusions may be drawn :

(*a*) At Angmagssalik reflection as well by day as by night is most frequently recorded at an effective height from 300-450 km. The records of this layer show the same character as those of the layer appearing in Delft only during night-time.

(*b*) A less frequently appearing layer was observed at an effective height of about 150 km.

Both layers are probably due to ionisation of the upper atmosphere by charged particles.

B. — The following conclusions may be drawn from the observatious on the signal strength of several short wave transmitting stations.

The reception of the 75 metre wave from Paris was better in winter than in summer and by night better than during day-time. For the wave lengths between about 40 m. and 25 m. the conditions of reflection were just opposite. The transmitting station at Tokyo working on a wavelength of 25 m. was heard rather regularly in winter as well as in summer (¹).

Delft, December 1934.

Nº 6. — **The nature of the solar radiation and the composition of the high atmosphere,** by Prof. S. Chapman.

Nº 7. — **Publications on radio wave propagation in « The report of radio research in Japan «.**

Propagation of wireless-wave, H. Nagaoka (Vol. 1, Nº 1).

(¹) An extensive report on the observations will appear soon in the *Tijdschrift van het Nederlandsch Radiogenootschap.*

On the propagation of the short waves, C. Anazawa, M. Asukai, M. Hattori, T. Hayasi, T. Minohara, T. Nakagami, O. Tanaka, K. Tani and E. Yokoyama (Vol. 1, N° 1).

Polarization phenomena of low-frequency waves, S. Namba (Vol. 1, N° 1).

Polarization of high-frequency waves and their direction finding, S. Namba, E. Iso and S. Ueno (Vol. 1, N° 1).

Variation of bearing observed in short-wave direction-finding, M. Asukai and T. Hayasi (Vol. 1, N° 1).

Echo signal in Japan, T. Minohara, T. Inoue and S. Ono (Vol. 1, N° 1).

Propagation of the broadcasting waves in Japan, Y. Takata and Y. Ito (Vol. 1, N° 1).

Radio telephony by ultra short waves, S. Uda (Vol. 1, N° 2).

Duplex radio telephony on few metres waves between ship and shore, S. Uda (Vol. 2, N° 1).

Long-distance receiving measurements of broadcast wave across the Pacific, S. Namba and D. Higara (Vol. 2, N° 1).

Measurements of the height of the Kennelly-Heaviside layer in Japan, T. Minohara and Y. Ito (Vol. 2, N° 1).

Polar echo of high-frequency radio waves, S. Namba (Vol. 2, N° 1).

Effect of meteors on radio transmission, H. Nagaoka (Vol.2, N° 1).

Communication tests for radio telephony by means of ultra short waves between Niigata and Sado, S. Uda (Vol. 2, N° 1).

Theory on the propagation of low-frequency waves, E. Yokoyama and S. Namba (Vol.2, N° 2).

A general theory of the propagation of radio waves in the ionized layer of the upper atmosphere, S. Namba (Vol. 2, N° 3).

Some long-distance transmission phenomena of low-frequency waves, E. Yokoyama and I. Tanimura (Vol. 2, N° 3).

Experiments on the ultra-high-frequency communications, T. Nakai, R. Kimura and S. Ueno (Vol. 3, N° 1).

Field strength measurements and directional observations of short waves, T. Nakai (Vol.3, N° 1).

Field strength measurements and directional observations of high-frequency radio waves at the Electrotechnical Laboratory, Ministry of Communications — I. (From September to December, 1932) (Vol. 3, N° 1).

Field strength measurements and directional observations of high-frequency radio waves at the Electrotechnical Laboratory, Ministry of Communications — II (From January to March, 1933), (Vol. 3, N° 2).

Field strength measurements and directional observations of high-frequency radio waves at the Electrotechnical Laboratory, Ministry of Communications — III (From April to August, 1933), (Vol. 3, N° 3).

Measurements of heights of the Kennelly-Heaviside layer in Japan — I (From August 1932 to January, 1933), Vol. 3, N° 1).

Measurements of the ionized layer heights in Japan, T. Minohara and Y. Ito (Vol. 3, N° 2).

Effect of the Leonid meteor shower on the ionized upper atmosphere, T. Minohara and Y. Ito (Vol. 3, N° 2).

Correlation of radio atmospherics with meteorological conditions, T. Ikebe (Vol. 3, N° 2).

Seasonal variations of signal intensity and the fading phenomena of some broadcasting stations, M. Kinase and S. Ueno (Vol. 3, N° 3).

On directional observation of long-distance short-wave stations and the relation between directional deviation and scattering in the ionosphere, T. Nakai (Vol. 3, N° 3).

On the transmission of short-waves through the North-Polar night zone, T. Nakai and M. Nakagami (Vol. 3, N° 3).

N° 8. — **Publications relatives aux recherches radioélectriques,** par le Dr. J. Lugeon, Secrétaire du Comité National Suisse.

Sur un nouveau procédé expérimental pour l'exploration des parasites atmosphériques, J. Lugeon. Archives des Sciences Physiques et Naturelles, vol. 7, p. 408-409; Nov.-Déc., 1925.

Les idées françaises sur la dynamique des parasites de la T. S. F. et leur extension en Suisse, J. Lugeon. Archives des Sciences Physiques et Naturelles, vol. 7, p. 406-408 ; Nov.-Déc., 1925.

Les atmosphériques des fronts quasi-stationnaires sur le versant nord des Alpes, J. Lugeon. Archives des Sciences Physiques et Naturelles, vol. 10, p. 67-74 ; Jan.-Fév., 1928.

Un appareil radio-électrique pour déceler l'origine géographique de l'air, J. Lugeon. Archives des Sciences Physiques et Naturelles, vol. 10, p. 311-312, Sept.-Oct., 1928.

La nouvelle méthode de sondage électromagnétique vertical et quasi-horizontal de l'atmosphère, J. Lugeon. Archives des Sciences Physiques et Naturelles, vol. 11, p. 239-259 ; Sept.-Oct., 1929.

Sur la portée des atmosphériques d'après les enregistrements simultanés de Paris-Zurich-El Golea (Sahara), Rochers de Naye (Suisse) et Varsovie, J. Lugeon et E. Nicola. Archives des Sciences Physiques et Naturelles, vol. 12, p. 17-18 ; Nov.-Déc., 1930.

Réfraction et Propagation des Atmosphériques dans la Troposphère, J. Lugeon. Assoc. Fran. p. Avanc. des Sciences, Le Havre, 1929.

Sondowanie warstw atmosfery za pomoca obserwacii zaklocen pola elektromagnetycznego (Le sondage par les parasites atmosphériques), J. Lugeon. Biuletyn Towarzystwa Geofizykow w Warszawie. (Bulletin de la Société Géophysique de Varsovie), vol. 1, 1931.

Relations entre diverses discontinuités météorologiques et les oscillations hertziennes parasites au voisinage des chaînes de montagnes, J. Lugeon. Comptes rendus, vol. 180, p. 594 ; 23 Fev., 1925.

Une méthode pour sonder l'atmosphère à l'aide des perturbations du champ électromagnétique au passage de l'anneau crépusculaire, J. Lugeon. Comptes rendus, vol. 188, p. 1114 ; 22 Avr., 1929.

La genèse des orages de chaleur et leur prévision à l'aide des atmosphériques, J. Lugeon. Comptes rendus, vol. 189, p. 363 ; 26 Août, 1929.

Ionosation et champ électrique à El Golea ; l'éclair visible à 800 km ; mirages en automobile ; condensation dans les dunes du Grang Erg, J. Lugeon. Comptes rendus, vol. 191 ; p. 216 ; 28 Juillet, 1930.

Le repérage radio-électrique des tempêtes de sable du Sahara à grande distance, J. Lugeon. Comptes rendus, vol. 191, p. 61 ; 7 Juillet, 1930.

Le sondage simultané par les parasites atmosphériques à Zurich et au Sahara, J. Lugeon. Comptes rendus, vol. 191, p. 525 ; 29 Sept., 1930.

L'éclipse de soleil du 31 Août 1932 et le sondage par les parasites atmosphériques, J. Lugeon Comptes rendus, vol. 195, p. 817 ; 7 Nov., 1932.

23 Avril 1934.

N° 9. — **Program of ionosphere measurements and forms for analyzing data,** by the National Bureau of Standards.

In order that data obtained by workers in different parts of the world, in the determination of heights and critical frequencies of the layers of the ionosphere, may be compared and used to the best advantage, it is desirable that some degree of uniformity be established in the times and types of observations and in the reduction of the results. A program of measurements being followed by the National Bureau of Standards and (in part) by the observatory of the Carnegie Institution in Peru, is presented. Tentative forms for analyzing results are included.

It is believed that simultaneous critical frequency runs should prove of greatest value. It is suggested that all runs begin on the half hour and should be from a lower to a higher frequency. Although the number of runs is not limited to one per hour it is desirable that the commencement of runs be synchronized once each hour.

Two types of runs are proposed for alternate Wednesdays. Type I, which covers the period 0030 to 2330 E. S. T., consists of measurements of heights and critical frequencies of E and F_1 layers during the day and of the E layer at

night. Type II consists of similar measurements for F_1 and F_2 layers during the day and for the F_2 layer at night. Between 1130 and 1230 one run is made through the entire band from below the critical frequency for the E layer to above that for the F_2 layer. Weeks of Type I in 1934 begin on January 7, 21, February 4, 18. etc., while those of Type II begin on January 14, 28, February 11, 25, etc.

In addition to the above, a record starting each hour throughout the day is to be made daily for the band 2500-4400 kc by the Bureau. At the Peru observatory observations are to be made also during the day on each Monday.

The tabulation should show for each layer : (1) the lowest virtual height, (2) rate of change of height with frequency, (3) range of frequency where change of virtual height is small, (4) frequency for beginning of magnetic splitting, (5) all critical frequencies, and (6) the character of the critical frequencies.

N° 10. — Terrestrial magnetism and its relation to world wide short wave communication,

by H. E. HALLBORG, R. C. A. Communications, Inc., New-York, N. Y.

The challenge to uninterrupted short wave communications presented by magnetic storms has led to practical study of terrestrial magnetism in terms of circuit performance.

When a particular magnetic observatory is used as a reference base, a definite change in the horizontal intensity may be related to a definite condition of the radio circuit. The observed limits, using Tucson as a reference base, are given.

Analysis of observations from the American observatories at San Juan, Tucson, Cheltenham and Sitka for the year 1931 provided a relationship between magnetic disturbance and North latitude.

The world's short wave communication zones during 1931 are shown on isogonimetric maps of the world about New York, San Francisco and Berlin. A dead zone of radius 15° about the north magnetic pole, and a disturbed zone of radius 28°, for that year, was established.

Westerly trans-Atlantic communication from Europe is less disturbed than Earsterly communication from America. The practical effect of this condition is that short wave commercial reception from Europe is relatively easier than is American commercial reception in Europe.

Magnetic storms are definitely associated with a drop in the mean horizontal intensity. The retentivity of demagnetization is shown by a series of graphs covering the year 1932.

The diurnal history of the storm of May 29, 1932 is shown graphically.

A chart based upon the 27 day cycle of magnetic recurrence, from Tucson magnetograms, for the years 1932 and 1933 is shown. Charts of this kind are now being maintained for the selection of favorable periods for international broadcasts.

In general, application of the observed variations in terrestrial magnetism permits the most effective use of facilities, at all times and seasons, in the maintenance of a world wide radio communication service.

N° 11. — Report on long distance broadcasting transmission (600-1 500 kc/s.). — Polarisation of broadcast waves-charts for short wave transmission. — Ultra-short wave transmission,

by T. L. ECKERSLEY.

This paper deals with :

(a) The extension of the range of the Madrid curves indicating the relation between field intensity and distance.

(b) The description of a radio polarimeter for determiming the direction of polarisation of downcoming waves and its use to reduce fading by eliminating the downcoming waves, and

(c) The theoretical modification of Watson's diffraction formula and its comparison with experimental results obtained on medium and ultra-short waves.

N° 12. — **The symbolic calculus with some applications to radio-telegraphy,** by Dr. B. van der Pol.

The report first summarises some historical details of Oliver Heaviside's methods of his « operational calculus », which was then founded more on empirical rules than on rigid mathematical foundations. The work of T. J. I. A. Bromwich and K. W. Wagner on the one hand and of J. R. Carson on the other hand put the operational calculus on a sound mathematical basis. The latter defined the operational representation (« image ») of a given function by a Laplace transform, while the complex integral of Bromwich and Wagner enables one to find back the original function from its « image ». The modern development does not leave room anymore for an « operator » and « operand » and it was therefore suggested to call the method the « symbolic calculus ». Thus e. g. the objection against a derivative of fractional order of a discontinuous function is totally removed. The report further gives a rather complete list of *Rules* applicable in the symbolic calculus, which for the greater part were derived by the present author. Thus the symbolic calculus becomes also available to the solution of *differential equations with variable coefficients* whilst formerly it could only be applied to differential equations with *constant* coefficients. Also a list of « images » is given, as well as several examples of applications a. o. treating Kelvin's *ber* and *bei* functions having as their image *cos* and *sin* functions respectively. Thus the ordinary goniometry can completely be « translated » in a series of relations of *ber* and *bei* functions. The author's method is also immediately applicable to linear *partial* differential equations and in the report an example is given how, with the aid of the symbolic calculus, from any two-dimensional wave function, which is dependent of φ, a solution of the one-dimensional heat-diffusion (or CR cable) equation can be derived. Finally a new general theorem is given, again derived with the symbolic calculus, enabling one to find the « indicial admittance » of a network wich is reciprocal as regards its frequency characteristic to another network of the « indicial admittance » of the latter is known.

A bibliography is appended (¹).

N° 13. — **Precision measurements of carrier frequencies by the aid of a valve-driven tuning-fork,** by Sven Gejer.

The following is a summary of practical results obtained in using standard-frequency transmissions now available for checking the frequency of a secondary frequency standard consisting, in this case, of a temperature controlled tuning fork with a frequency of about 1,000 c/s.

The standard frequencies used are those transmitted from the National Physical Laboratory in England and the Bureau of Standards in U. S. A. In both cases the comparisons between the tuning-fork frequency and the transmitted standard frequency can be made with an accuracy of about 0.3 parts in a million. Measurements made over a period of more than a year have shown that the frequency of the own substandard it at every time known with an accuracy better than 1 part in a million.

For measuring the frequency of a carrier wave as compared with the tuning-fork frequency, the following method is used : by the aid of a multivibrator it is possible to adjust a series of heterodyne-wavemeters to harmonics and « half » harmonics of the fundamental tuning-fork frequency. The interfering tone between the sought carrier frequency and its most adjacent tuning-fork harmonic is determined by the aid of a low-frequency oscillator calibrated against harmonics and subharmonics of the tuning fork. This interfering tone need not exceed 500 c/s for frequencies below 1,500 kc/s and 3,000 c/s for frequencies below 20 mc/s. In most cases the comparison between the

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(¹) The full document will be published in the *Tijdschrift van het Ned. Radio Genootschap,* 1935.

sought frequency and the tuning-fork harmonic can be made with an accuracy of about 1 c/s. Thus the total error in a frequency measurement needs not to exceed ± (10^{-6} + 1 c/s). (¹)

N° 14. — **Measurement of velocity of radio waves** by Dr. A. N. GOLDSMITH. — (Full text).

A method of measuring the velocity of radio waves might be developed through the use of multiple echoes. Suppose station A in Europe were to send a single extremely short pulse to statio B in America. The pulse might be, for example, less than a thousandth of a second in length and must be shorter than the time of transmission from station A to B. Station B automatically repeats the signal back to A, and A repeats it back to B and so on. The signals are recorded and the time delay of repetition within the station in each case is measured on local signals. By repeating a signal back and forth across the ocean a sufficient number of times increasing precision of measurement becomes possible.

To determine the length of path actually traversed by the waves, a statistical basis might be used. That is, after a great many observations of apparent wave velocity were made by the method of multiple echoes, these would presumably center around some average or norm. If only a single transmission path were found in some cases, and without echoes on each pulse, possibly the length of the relatively simple path might be deduced. Another way of tackling the problem would be to have several intermediate receiving stations which could pick up the signals from each of the two distant transmitting stations and thus give additional information as to the course of the wave in its path from one station to the next.

June 22th, 1934.

N° 15. — **Selection of frequencies for recording atmospherics,** by H. T. FRIIS, Chairman of Technical Committee on Atmospherics, American National Committee. — (Full text).

The resolutions adopted by Commission III at Copenhagen proposed the establishment of 12, 50 and 90 kc/s as frequencies for the recording of atmospherics. It is suggested that a selection of frequencies fairly evenly spaced over the whole radio spectrum would be more useful. I propose for this purpose 12, 60, 300, 1.500, 7.500 and 20.000 kc/s. A member of my committee has suggested for consideration also 4.000 and 15.000 kc/s.

June 19th, 1934.

N° 16. — **Atmospherics of interstellar origin,** by the American National Committee. — (Full text).

These atmospherics, propagated in a fixed direction in interstellar space, were described in the paper, « Electrical disturbances apparently of extraterrestrial origin », by K. G. Jansky(¹), The following proposals are made for consideration by the U. R. S. I.

It is suggested (1) that a study of the variation of the direction of arrival of these atmospherics with time of day and day of year be made at several stations scattered widely over the surface of the earth, and (2) that a study be made of the variation of intensity of these atmospherics with frequency. The information obtained under the first suggestion would help not only to confirm the existence of these waves but to determine the direction of arrival in space more accurately than has heretofore been done. That obtained under the second suggestion would help to determine the true character of these atmospherics, and would give some clue as to their source and method of propagation to the earth (²).

It would seem interesting to make simultaneous and synchronized observations of the

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(¹) *Tecknisk Meddelanden fran Kungl. Telegrafstyrelsen*, 1934, p. 85.

(¹) *Proc. I. R. E.*, vol. 21, pp. 1387-1398; Oct. 1933.

(²) K. G. JANSKY, Bell Telephone Laboratories.

short wave static at different stations. The time lag so observed should give information about the path followed by the static ascertaining the elevation of its direction. My particular reason for suggesting this is that the technique used in observing echoes would be useful in performing such an experiment and that some of the members may be in a position to try it out. A possible method of synchronization is to use the ground wave sent from one of the stations. It should also be very interesting to vary the frequency band of the receiving system. If this static comes from interstellar space it should give a tool for studying the ionosphere through its depth while the ordinary observations of virtual heights give only information by looking at it from below (¹).

July 12th, 1934.

Nº 17 — **Radio Field Strength Measurement,** by C. R. Englund.

Nº 18. — **Auxiliary apparatus for operating Kennelly-Heaviside layer height recorders,** by H. Rowe Mimno and Pao Ho Wang, Cruft Laboratory, Harvard University, Cambridge, Mass.

In a previous paper (²), we described two types of automatic recorders which we developed for the continuous study of changes in the effective heights of the Kennelly-Heaviside layers. In the same paper we reported the results obtained by our field expedition at the time of the total solar eclipse of August 31, 1932. Since that date no fundamental changes have been made in the recorder mechanisms, but a number of further improvements have developed in the associated transmitting and receiving circuits. These changes are intended to adapt the equipment for use in a permanent ionosphere observatory, comparable with magnetic observatories.

To minimize interference with other services during automatic continuous daily operation on two frequencies, duplicate crystal-controlled transmitters have been built. As a further precaution against frequency drift, automatic monitor units have been developed, which stop all transmission in case the carrier wave shifts 0.02 per cent.

The band width is also well limited. Pulse modulation, produced by an auxiliary thyratron circuit, is introduced in the plate circuit of a low-power stage of each transmitting set. After leaving this tuned tank-circuit, the modulated wave passes through *four additional* sharply-resonant circuits, which further limit the side-bands to the minimum value consistent with the formation of a properly defined signal.

Call letters are sent automatically at 15 minute intervals, with a somewhat longer transmission at the beginning of each hour. These interruptions provide a convenient synchronized time-scale on all records. A five-minute interruption occurs at midnight.

Receiving and recording devices, mounted in closed boxes on automobile trailers, have been left in distant cities, synchronized on the same alternating-current power net; and have operated successfully during 14 day intervals without readjustment or other attention.

Balanced receiving sets have been used in some cases in order to obtain maximum sensitivity at points directly under the transmitting antenna.

Additional experiments are being conducted with field transmitting sets, polarized receivers, and new methods of synchronization (¹).

(¹) G. Breit, New-York University.

(²) H. R. Mimno and P. H. Wang, *Proc. I. R. E.*, vol. 21, p. 529, 1933.

(¹) Part of the material covered by this paper has been published in the Proceedings of the Fifth Pacific Science Congress (1933). Additional material will be published in the Proceedings of the Institute of Radio Engineers at a later date.

No 19. — **Analysis of a 6.000 hour record of Kennelly-Heaviside layer heights,** by H. Rowe Mimno and Pao Ho Wang.

The rapidly increasing use of automatic apparatus in recording continuously the daily fluctuations of the effective heights of the Kennelly-Heaviside layers, permits a detailed examination of normal and abnormal changes in the ionization of the upper levels of the earth's atmosphere. During most of the 6.000 hour period covered by this report, simultaneous records were made on two frequencies. The resolving power of the apparatus is sufficient to record magneto-ionic double-refraction in the E layer, as well as in the F layers.

From the average rate of decay of ionization on normal days in Fabruary, March and April, 1933, the mean value of the corresponding recombination cœfficient is estimated to be 4.3×10^{-10}. According to the result of a penetration-frequency test on February 15, the maximum electronic density at noon was about 1.08×10^{6}; and the equilibrium value of the ionizing power was approximately 500 electrons per cc. per second.

The sudden and violent fluctuations which occur during magnetic storms have been studied by means of an auxiliary high-speed « fine-structure » recorder. In some cases at least five distinct « layers » appear in the F region (in addition to the usual multiples).

In addition to these short-period fluctuations, there appears to be a definite correspondence between the magnetic cycle, the average F-layer height, and the hour of the day at which the F-layer is penetrated by the extraordinary component of the 4095 kilocycle wave.

We have also examined the frequency of occurence of 4095 kilocycle E-layer reflections during a three month period, (April, May and June 1933). Sudden abnormal increases of ionization (during the hours of darkness) were most common about 4 a. m. When these are observed in Cambridge they are likely to be found in Washington on the same date but at a different time. The preliminary results do not indicate any definite time sequence, and it is possible that these reflections are due to local clouds of ions, moving more or less at random (¹).

No 20. — **A universal unit for measuring atmospherics,** by H. T. Friis.

Contributions made to a symposium on the above subject held in Washington, D. C. on April 29, 1932, and presided over by Mr. H. T. Friis.

Mr. H. T. Friis gave a summary of the methods of measuring atmospherics used in the past and pointed out the need for a universal or standard unit in terms of which all data on atmospherics should be expressed. He suggested the micro-volt per metre, the data being reduced to the case of a receiver having a band width of 1 kilocycle, as the proper unit.

He discussed the different types of static and suggested that a brief discussion of the types heard in connection with the intensity measured in the above unit might give information that would greatly aid those interested to estimate the interfering effect of atmospherics.

Mr. W. W. Mutch described an automatic field strength and atmospheric recorder. His paper appeared in full in the Proc. I. R. E., Vol. 20, No 12, page 1914, Déc. 1932.

Mr. K. G. Jansky showed how the band width of a receiver should be measured, and discussed the effect that changing the band width has on the value registered by the recorder when various methods of recording are used.

Mr. R. K. Potter pointed out the difficulties encountered in making measurements of atmospherics at very high frequencies and discussed a method whereby the peak voltages of the individual crashes is used as an estimate of the intensity of the atmospherics when other methods of measurement fail.

(¹) Part of the material covered by this paper has been published in the Proceedings of the Fifth Pacific Science Congress (1933).

Additional material will be published in Physics at later date.

M. R. S. Tucker discussed the methods that are now being developed on the telephone plant for the measurement of noises of all types. In particular he discussed the ear balance method, the noise meter, and the sound meter.

There followed a brief discussion between Mr. Friis and Mr. Austin relative to the advisability of recommending a standard method of recording as well as a standard unit for expressing the results (1).

N° 21. — **Sur l'étude en laboratoire des propriétés diélectriques des gaz ionisés,** par C. Gutton, Directeur du Laboratoire National de Radioélectricité à Paris.

Des mesures de constante diélectrique des gaz ionisés (2) ont montré qu'il se produisait dans un volume limité de gaz, contenu dans un tube de verre, des phénomènes de résonance électronique. La fréquence de résonance est d'autant plus élevée que l'ionisation est plus intense et l'acuité de la résonance d'autant plus grande que la pression est plus faible.

Il est possible de concevoir que ces phénomènes peuvent se produire dans l'atmosphère (3), dont l'ionisation n'est pas uniforme dans un volume assez grand pour qu'on puisse lui attribuer des dimensions indéfinies vis-à-vis de la longueur d'onde. Il y a lieu d'ailleurs d'observer que dans la théorie de Eccles la vitesse de phase et par suite de la longueur d'onde augmentent indéfiniment lorsque l'indice tend vers zéro.

Si ces phénomènes de résonance existent dans l'atmosphère, une reflexion sous l'incidence normale doit se produire sur la couche en résonance.

Comme d'autre part les phénomènes de résonance sont dus à la répétition rythmée d'un grand nombre d'ondes successives, un signal émis par un poste à ondes entretenues, qui, quoique bref, comprend un grand nombre de périodes, doit être plus parfaitement réfléchi qu'un train d'ondes très amorties produit par la décharge par étincelle d'une antenne. L'expérience (1) confirme ce fait et le résultat est d'accord avec l'idée d'une réflexion sur une couche en résonance.

N° 22. — **La génération d'oscillations électriques de longueur d'onde inférieure à 1 mètre,** par K. W. Wagner et H. E. Hollmann (2).

Lorsque l'on cherche à engendrer des ondes électriques de plus en plus courtes à l'aide de tubes électroniques, de grandes difficultés apparaissent dès qu'on s'approche d'une limite fixée approximativement par le mètre

Les circonstances d'entretien deviennent de plus en plus défavorables, mais leur influence peut être contrebalancée par une évolution appropriée du système oscillant, ainsi par exemple, par l'emploi de connexions tubulaires concentriques ou de circuits de grille en spirale.

Pour ce qui concerne l'élimination de l'influence du déphasage dû au temps de transit des électrons, deux moyens se présentent.

On peut, d'une part, réduire les temps de transit par une réduction proportionnelle des dimensions des tubes, de façon à ce que ces tubes ne souffrent pas de ce déphasage, même pour des ondes de l'ordre de grandeur du décimètre.

On peut, d'autre part, mettre en œuvre des procédés basés sur l'appropriation du temps de transit final δt, lesquels sont alors en relation avec la fréquence ω et obéissent à la relation d'inversion

$$\omega \ \delta t = \pi . n$$

où n représente la série des nombres entiers.

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(1) The above symposium has not been and probably will not be published. Complete copies giving the discussion in full may be obtained by writing to Mr. H. T. Friis, c/o Bell Telephone Laboratories, P. O. Box 107, Red Bank, New Jersey, U. S. A.

(2) H. Gutton, *Onde Electrique*, t. 6, p. 137, 1927 et t. 7, p. 1, 1928; *Annales de Physique*, t. 13, janvier 1930.

C. Gutton, *Annales de Physique*, t. 14, p. 5, 1930.

(3) C. Gutton, *Onde Electrique*, t. 12, p. 6, 1933.

(1) C. Gutton, J. Calle et H. Joigny, *Comptes rendus de l'Académie des Sciences*, t. 199, p. 470, 1934.

(2) Le texte complet a été publié dans le E. N. T. de décembre 1934.

Le dispositif qui utilise le temps de transit final est l'oscillateur à champ retardateur d'après Barkhausen et Kurz.

Les oscillations étaient attribuées à l'origine à un mouvement pendulaire d'électrons autour de la grille positive.

D'après des recherches plus récentes, elles proviendraient de l'appropriation d'un circuit résonant dont les conditions d'entretien tiendraient compte non seulement des déphasages ultra-dynamiques à l'intérieur du tube, mais également des rétroactions résultant des connexions.

Les oscillations d'ordre supérieur, connues généralement sous le nom de « micro-ondes » répondent au domaine de classification de la formule d'inversion caractérisée par n, d'où la relation plus générale $n^2\lambda^2 Eg$ = constante peut être déduite.

On peut considérer le magnétron comme forme particulière de l'oscillateur à champ retardateur, dans lequel le champ retardateur électrostatique d'anode est remplacé par un champ magnétique.

Si le cylindre anodique est découpé en deux ou plusieurs segments, il naît entre les segments une résistance négative qui peut exciter, à de très hautes fréquences, un système résonant.

Le rendement atteint 50 % pour une onde de 50 cm. et avec un cylindre de 1 m/m de diamètre, on peut atteindre l'onde de un centimètre. Au delà de cette limite, on est encore tributaire de l'excitation par étincelle qui constitue la transition entre les dipoles herziens macroscopiques et les dipoles moléculaires.

Enfin, la question se pose de savoir s'il y aura possibilité de dépasser beaucoup cette limite de l'onde d'un ordre de grandeur du centimètre, sans être gêné par la constitution énergétique de l'atome et de la molécule.

N° 23. — **Effective height of antennas,** by P. E. Watson, Signal Corps Laboratories, Ft. Monmouth, N. J., U. S. A.

1. The term effective height of an antenna has been used at different times to indicate the relative merits of antennas. This term can be calculated and used to some advantage when the frequencies involved are less than approximately 400 kc, an the antennas are those types which have loading at the top resulting in approximately uniform current in the vertical lead.

2. The usual method of determining the effective height of an antenna under the above conditions is by measuring at a distant point the intensity of the field radiated by the antenna when excited by a transmitter, and then calculating the effective height from formulas developed by different men.

3. These formulas are theoretical ones developed to give the effective value of the electric or magnetic field at a distant point from the antenna. Morecroft gives the formula

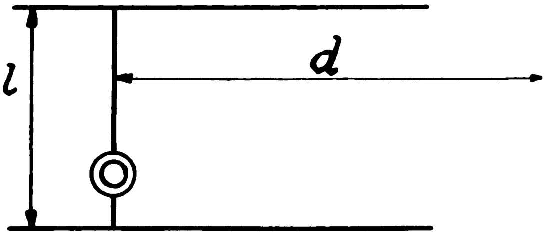
$$E = \frac{600\,\pi l\, I}{10\,\lambda d} \quad (1)$$

Where :

E = effective value of electric field in volts per cm.

I = effective value of the current in antenna, in amperes,

l, λ, and d are in centimetres.



This formula reduces to

$$l = \frac{\lambda\, dE}{188.5\, I \times 10^6}$$

Where :

E = microvolts per metre.

l, λ, and d are in metres.

As stated above the use of this formula is limited to the types of antennas shown and to

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(1) Principles of Radio Communication, 2nd Ed., page 823.

the low frequencies, where the attenuation is proportional closely to $\frac{l}{d}$.

Also this formula appears to be in error by a factor of two. These Laboratories have made measurements of effective height of a number of antennas by very accurately determining the field intensity. When the formula as given by Morecroft was applied, results invariably obtained were twice the actual physical height of the antenna, indicating that the correct formula should be

$$1 = \frac{\lambda\, dE}{377\, I \times 10^6}$$

A typical example of such a calculation on the antenna and counterpoise system shown, is given.

4. It is believed that some authorities give this constant of 377 instead of 188.5, but definite information is not at hand at present.

5. Evidently there is a need for a more accurate treatment of this subject than can be found in the present literature, if it is to be of any value for design purposes.

6. Also at present the use of the term effective height of antenna is of questionable value when used in connection with the shorter waves and great variety of antennas used to propagate them. It is the opinion of these Laboratories however that, if possible, an accurate treatment of the simple vertical antenna to permit calculation of ground wave propagation would be of considerable value. Considerable data should be available now since so many broadcasting stations have adopted some form of vertical antenna a quarter wave or more in height.

July 10, 1934.

N° 24. — **A determination of some of the properties of the piezo-electric quartz resonator,** by KARL S. VAN DYKE, Wesleyan University, Middletown, Conn.

Entirely consistent determinations of the logarithmic decrement of X-cut quartz rods whose natural frequencies are of the order of 70 kc have been obtained during the last few years. The decrement is obtained from measurements on oscillographic records of the decay of the free vibrations of the resonator. The most extreme (lowest) values of decrement have been checked by an entirely independent method, namely, by tracing the resonance curve, the agreement between the two methods being to within a few per cent. Extended studies by the former method have shown the logarithmic decrement to be a linear function of the pressure of the surrounding gas, and the energy losses in the two gases tried, air and hydrogen, to be in the ratio of their radiation resistances. This assumes precious elimination of mounting losses, which for ordinary mountings are even larger than radiation losses. When radiation losses have been eliminated, the effect of the abrasive used in making the usual ground finish of the surfaces of the quartz becomes obvious, the lowest decrements being obtained when the surfaces have been etched. Representative logarithmic decrements measured under various conditions are as follows, the corresponding reactance-resistance-ratio (Q) being inserted in parentheses following each logarithmic decrement.

Ground surfaces, in air at atmospheric pressure,

126×10^{-6} (25,000)

Ground surfaces, in hydrogen at atmospheric pressure,

31×10^{-6} (101,000)

Ground surfaces, in vacuum,

$11\text{-}17 \times 10^{-6}$ (290,000-180,000)

Etched surfaces, in vacuum,

6.4×10^{-6} (490,000)

Etched surfaces, polished, in vacuum,

5.4×10^{-6} (580,000)

Decrements quoted are for short-circuited resonators with thin silver electrodes chemically plated into the crystal, the short-circuit values being obtained by extrapolation from determinations at various resistance loads. The method yields also the resistance and inductance elements of the equivalent network (Proc. I. R. E., Vol. 16, p. 742-764, 1928), and further by the equations for the network a value 5.29×10^4 cgs for the piezo-electric cœfficient which is effective in driving Y-waves in X-cut rods. Temperatures are of the order of 27° C throughout. Resonator dimensions are $0.5 \times 4.0 \times 0.5$ cm along X, Y, and Z respectively (¹).

N° 25. — **Memorandum on sunspots,** by J. C. Schelleng, Bell Telephone Laboratories. — (Full text).

This memorandum is written at the suggestion of Dr. Dellinger, Vice Chairman, American Section, U. R. S. I., to set down two subjects which it may be of interest to discuss at the London meeting :

(1) It would be of importance for the science of radio transmission if, by visual observation of the sun, we could identify and observe the specific solar disturbance which produces a given disturbance in radio transmission. This would also be important for terrestrial magnetism. All efforts along this line seem to fall short of a satisfactory correlation; at the same time they lead to the tantalizing conviction that observations of the right kind would yield definite results, if only we knew what observations to make. With the spectrohelioscope, a number of observations of violent solar eruptions of short life have been made by various investigators which were followed by intense magnetic storms. If the sun were under observation at all times, all large eruptions would be found and it might ensue that most terrestrial disturbances can be accounted for in this way. Several observers are required at different locations about the earth in order to keep the sun under observation and Dr. G. E. Hale (to whom this suggestion seems to be due) has been trying to organize this sort of astronomic program, employing as many spectrohelioscopes in different longitudes as can be enlisted in the project. Such a program should begin modestly, at first perhaps limiting the observations to a week's program; this might well be made 27 days after a severe magnetic storm in order to take advantage of the tendency for storms to recur with each solar rotation. If it is desirable for radio scientists to take any steps to coordinate their work with that of the astronomers, it would appear that the U. R. S. I. might be the ideal organization through which to work. The U. R. S. I. might find it desirable to have some committee investigate the possibilities.

(2) In line with a subject already proposed for discussion, « directive effects in the vertical plane, and variations with magnetic disturbances », it would be of scientific value to know comprehensively what transmission paths are free from serious effects during magnetic storms, and what paths are seriously affected. It is known qualitatively that northern latitudes are the more subject to these disturbances and it is felt by many that a *definite* correlation must exist between the radio phenomena between any two points, and the proximity of the corresponding great circle to the zone of maximum auroral occurence. Can the severity of disturbances in radio transmission be correlated with the maximum prevalence of aurora along the great circle path or with the magnetic latitude ?

July 12th, 1933.

N° 26. — **Distribution of radiation in vertical plane for communication with short waves over great distances,** by C. W. Latimer.

This paper describes three methods of determining the angle of projection from a radio transmitter in order to ascertain the optimum angle for any communication circuit.

(¹) The complete paper as submitted to the General Assembly has been submitted to the Institute of Radio Engineers for publication.

N° 27. — **Report of radio research in Japan,** by the National Research Council of Japan.

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N° 28. — **Measurements of the heights of the Kennelly-Heaviside layer in Japan,** by TSUTOMU MINOHARA and YÔJI ITÔ (³).

(¹) Paper N° 29, p. 146.

(²) Paper N° 30, p. 146.

(¹) Paper N° 31, p. 146.

(²) Paper N° 32, p. 146.

(³) *Rep. of Rad. Res. in Japan*, vol. III, N° 1, 1933.

N° 29. — **Field strength measurements and directional observations of short waves,** by TOMOZÔ NAKAI, Electrotechnical Laboratory, Ministry of Communications, Tokyo (¹).

A brief account is given of the field strength measuring apparatus, recently designed and set up at our laboratory. A vertical aerial is employed. The calibration of the over-all gain by the vertical aerial and its tuning circuit was made by comparing it with a loop, taking into consideration the effect of wave absorption due to surrounding objects. In order to check the performance of the apparatus, it was compared with a Western Electric high-frequency field-strength measuring set, when good agreement was obtained, the difference being within 1 or 2 decibels.

Directional observations were also conducted by using a high-frequency direction finder of a new goniometer type which was recently designed and constructed at our laboratory. Its working is very satisfactory and entirely free from the error due to wave polarization. Directions may usually be determined within errors of about ± 1 or ± 2 degrees.

N° 30. — **Field strength measurements and directional observations of high-frequency radio waves at the Electrotechnical Laboratory, Ministry of Communications,** by TOMOZÔ NAKAI (²).

The results of Field Strength measurements and directional observations conducted at the Electrotechnical Laboratory, Ministry of Communications are presented in curves and figures.

The principal Stations selected for the observation are New York, San Francisco, Rio de Janeiro, Buenos Aires, London, Berlin, Melbourne, etc.

The results of the observation for a period of Sept. to Dec., 1932, are included in Part I, Jan. to March, 1933 in part II, and April to Aug., 1933 in Part III.

N° 31. — **On directional observation of long-distance short-wave stations and the relation between directional deviation and scattering in the ionosphere,** by TOMOZÔ NAKAI.

This paper describes the results of directional observations carried out with long-distance short-wave stations outside the skip distance, at the Hiraiso Branch of the Electrotechnical Laboratory, since the autumn of 1932. These results show that waves may arrive from directions deviating by more than ten degrees or even several decades of degrees from the true direction at almost regular times of the day. These deviations appear to be due to scattered waves from the ionized medium about the transmitting station. These results also show that the ionosphere is made up of ionic clouds of a very complicated nature, in which scattering plays an important role in the propagation of short waves (¹).

N° 32. — **On the transmission of short waves through the north-polar night zone,** by TOMOZÔ NAKAI and M. NAKAGAMI.

This paper is a preliminary report on the authors' field-strength measurements and directional observations carried out between December 1932 and February 1933 with oncoming short waves from the New York and the Rio de Janeiro stations, both of wich were supposed to propagate through the polar night zone at the North pole. Our experiments have shown that the waves from these stations scarcely come from the true direction, but arrive from quite unexpected quarters. It appears that short waves are very difficult to propagate through the north polar night zone through details in regard to the ionization in this zone are still unknown (²).

(¹) *Rep. of Rad. Res. in Japan*, vol. IV, n° 2, 1934.

(²) *Rep. Radio Res. Japan*, vol. III, n° 1, 2 and 3, 1933, p. F1, F25, F53.

(¹) *Rep. Radio Res. Japan*, vol. III, n° 3, 1933, p. 251.

(²) *Rep. Radio Research. Japan*, vol. III, n° 3, 1933, p. 259.

N° 33. — **Thermal characteristics of piezoelectric oscillating quartz plates,** by I. Koga.

Piezoelectric oscillating quartz plates having very small temperature coefficient are divised and applied to the short-wave radio transmitter under commercial service with very good results. The temperature coefficients of the frequency of quartz plates, as such as X-cut and Y-cut plate, are generally somewhat higher than those which are ever reported. It is because the plates used in our experiements are sufficiently thin, so that the values of the temperature coefficients become their asymptotic values. By the way, the procedures of the preparation of test pieces and the measurement of the temperature coefficient of frequency are explained (¹).

N° 34. — **Quartz plates with a very small temperature coefficient of oscillation frequency,** by Sadao Matsumura and Shizuo Kanzaki, Electrotechnical Laboratory, Ministry of Communications, Tokyo.

The temperature coefficient of oscillation frequency of a quartz plate depends upon its dimensions and orientation against the crystallographic axes. In an ordinary X-cut (or Curie-cut) rectangular quartz plate, the temperature coefficient of frequency of the so-called Y-wave has already been found by the authors to become smaller as the ratio of the lenght measured along the Z-axis to that along the Y-axis becomes smaller (²).

The present paper describes the results of the experiments carried out thereafter with regard to the method of obtaining a quartz plate having a very small temperature coefficient of oscillation frequency. The new method of preparing such desirable plate is to cut a rectangular X-cut quartz plate from the crystal in such a manner that its lengthwise edges subtend a proper angle against the Y-axis. There exists an optimum dimensional ratio of breadth to length in order to give a minimum temperature coefficient of frequency for each angular orientation against the Y-axis.

For example, in the case of an X-cut rectangular quartz plate having the dimensional ratio of 0.5 and the angular orientation of -20° against the Y-axis, the temperature coefficient of frequency of the Y-wave was found to be less than -1×10^{-6} (¹).

N° 35. — **Ionospheric measurements at Losap Island during the solar eclipse of February 14, 1934,** by Ken-ichi Maeda.

The author describes and discusses the results of the measurements of apparent heights of the ionosphere by the pulse method carried out at Losap Island, one of the East Caroline Islands, during the solar eclipse of February 14, 1934. It is found that the ultra-violet radiation from the sun is the prominent agent of the atmospheric ionization, and the effect of the neutral corpuscle from the sun is slightly observed and ends earlier on the F-layer than on the E-layer.

The results of the measurements of electron densities in the ionosphere and the noise level in the vicinity of Losap Island are also described briefly.

As an appendix the principal results of the ionospheric measurements in North-America and Europe during the solar eclipse of August 31, 1932, are tabulated and compared with results of our experiments (²).

N° 36. — **Ionosphere heights measured in the South Sea Island and radio observations made during the solar eclipse of February 14, 1934,** by Tsutomu Minohara and Yôji Irô.

Radio observations of the heights of the layers of the ionosphere were made by means of the pulse method at Losap Island in the South

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(¹) *Rep. Radio Res. Japan,* vol. IV, n° 2.

(²) On the temperature coefficient of frequency of Y-wave in X-cut quartz plate, *Rep. Radio Res. Japan,* vol. II, n° 1, 1932, p. 85.

(¹) *Rep. Radio Res. Japan,* vol. IV, n° 2, 1934, p. 105.

(²) *Rep. Radio Res. Japan,* vol. IV, n° 2, 1934.

Seas during the period from February 1 to 17, 1934, especially on the day of the solar eclipse, February 14. On several days critical frequency measurements were also made.

We found considerable differences in the mode of wave propagation in th South Seas as compared with that in the Tokio district and, as might be expected, the heights of the E-layer were somewhat lower in the South Seas than in Tokyo. The results obtained from critical frequency measurements enabled us to determine the existence of the echo region and the absorption region in the range of the middle and the short wave. In the course of our measurements, we came upon a special absorption phenomenon, which we have called the « noon phenomenon ». The value of the ion density of the E-layer underwent marked changes with the progress of the eclipse. The states of the F-layer also changed and there was also an anomalous rise in the layer heights. The effect of the neutral corpuscles on the ionosphere could not be observed as the frequencies employed were not quite suitable for observing the state of the E-layer at the calculated time of the corpuscular eclipse. Observationally, it did not effect the F-layer, the frequency having been merely for the observation of the F-layer (1).

N° 37. — **Summary of some theoretical contributions of the problem of propagation of radio-waves over the earth,** by Dr. B. VAN DER POL and Dr. K. F. NIESSEN.

The report concerns the following papers :

I. Balth. van der Pol and K. F. Niessen. — Ueber die Ausbreitung elektromagnetischer Wellen über eine ebene Erde, Ann. der Phys., 6, 273, 1930.

II. Balth. van der Pol and K. F. Niessen. — Ueber die Raumwellen von einem vertikalen Dipolsender auf ebener Erde, Ann. der Phys., 10, 485, 1931.

III. K. F. Niessen. — Ueber die entfernten Raumwellen eines vertikalen Dipolsenders oberhalb einer ebenen Erde von beliebiger Dielektrizitätskonstante und beliebiger Leitfähigkeit, Ann. der Phys., 18, 893, 1933.

I*a*. Balth. van der Pol. — Ueber die Ausbreitung elektromagnetischer Wellen, Zts. f. Hochfreq. Techn., 37, 152, 1931.

I*b*. K. F. Niessen. — Bemerkung zu einer Arbeit von Murray und einer Arbeit von van der Pol und Niessen über die Ausbreitung elektromagnetischer Wellen, Ann. der Phys., 16, 810, 1933.

In these papers the solution of the wave equation for a transmitter, considered either as an electric or magnetic dipole above a finitely conducting flat earth obtained by *Sommerfeld* (1) is extended in several directions so that the results are more amenable to physical and numerical interpretation. It is shown that, for the case of both transmitter and receiver on the ground, the exact expression can considerably be simplified. A simple approximation leads to *Sommerfeld's* well known ρ formula and a further approximation thereof. For the field above the ground formula are obtained expressing this field as the sum of (*a*) a direct radiation and (*b*) a reflected radiation. The spacial ranges where this reflection formula is valid are discussed in great detail.

In these papers a frequent use is made of the symbolic calculus, this simplifying many intricate processes (2).

N° 38. — **Laboratory investigations of the dielectric constant of ionised air,** by Prof. E. V. APPLETON, F. R. S.

1. The existence of the quasi-resonance effect discovered by Gutton has been confirmed.

2. Contrary to the results of Gutton, the quasi-resonance effect has been found to depend on the circuit conditions.

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(1) *Rep. Radio Res. Japan*, vol. IV, n° 2, 1934.

(1) *Ann. der Phys.*, 28, 665, 1909.

(2) The full document will be published in the *Tijdschrift van het Ned. Radio Genootschap*, 1935.

3. By making observations for a range of wave-lenghts (λ), and also measuring the electron densities (N) to produce the Gutton effect it has been found that $N\lambda^2$ is a constant whereas Gutton found that $N^{3/4}\lambda^2$ was constant.

N° 39. — **Note of the generation of stable ultra-high frequency oscillations,** by F. A. Kolster.

N° 40. — **Transmission and reception of nine-centimetre wave,** by G. R. Kilgore, Research and Development Laboratory, R. C. A. Radiotron Co., Inc., Harrison, N. J.

Beam transmission with portable equipment requires the utilization of wavelengths below 10 centimetre. To demonstrate some of the possibilities in this field, an experimental 9 centimetre beam transmitter was built, employing a new type of electronic oscillator.

This oscillator consisted of a spilt-anode magnetically-controlled tube with the oscillating circuit completely within the bulb. The normal operating plate voltage and current were 1100 volts and 5 m. a. The output was estimated as 5.0 watt.

In the transmitter the 9 cm oscillator was plate-modulated by a 600 kc. oscillator which was in turn modulated by the voice frequency. The output of the transmitter was supplied to a dipole antenna through an adjustable transmission line. The directive system consisted of a 60 cm parabolic search-light reflector, and a hemispherical back reflector which was approximately half wavelength in diameter.

The reflector and transmitter ware mounted as a unit in a cabinet 26″ × 26″ × 14″, the total weight of the equipment being 180 pounds. The apparatus was designed to operate from 110-volt 60-cycle line and required an input of 165 watts.

The receiver consisted of a special positive-grid triode detector followed by a 600 kc. amplifier. The detector tube was mounted in back of the reflector the signal being supplied to the grid circuit through a tuned transmission line. Comparison with a crystal detector showed that the output was about ten times as great, but due to inherent noise in the tube the maximum sensitivity was about the same.

Successful telephone communication was carried on at a distance of one mile at which distance the field strength was sufficient to indicate a possible range of several miles.

N° 41. — **An electron oscillator with plane electrodes,** by B. J. Thompson and P. D. Zottu, Research and Development Laboratory R. C. A. Radiotron Co (¹).

It is well known that three-electrode thermionic vacuum tubes of cylindrical symmetry are capable of producing high-frequency oscillations of the Barkhausen-Kurz or Gill-Morrell types, in which the frequency is a function of electron transit time, but that modified parallel-plane structures, such as those having V- or W-type filaments are usually incapable of such oscillations. This difference is tentatively attributed to the lack of equal outgoing and returning electron paths in the flat structures. Structures designed to produce such equality of paths are described in which the cathode consists of a W-type thoriated tungsten filament, with a plane grid and plate on one side of the cathode and a single plate, called a backing plate, on the other. All these plane electrodes are mutually parallel.

When the grid is operated at a positive potential and the two plates at negative potentials, and a parallel-wire system is connected between the two plates, oscillations are produced. It is found that the backing plate must be at a negative potential and that there is an optimum value of this potential which is a function of the grid potential. It is observed that oscillations are readily produced with space-charge-limited emission, contrary to the usual behavior of cylindrical Barkhausen-Kurz tubes. It is further observed that only mode of oscillation is obtained with these tubes.

(¹) *Proc. Instit. Radio Eng.*, Déc. 1934.

Since only a narrow range of frequencies may be produced at a given grid voltage, and since the output and frequency are relatively independent of cathode temperature, it appears that these four-electrode tubes should be unusually stable as electron oscillators.

A tube of small dimensions incorporating a backing plate is described which produced oscillations at a wavelength of less than 10 cm at a grid potential of 150 volts and a grid input power of 3 watts.

No 42. — **Radio frequency standards,** by E. L. Hall, V. E. Heaton, and E. G. Lapham National Bureau of Standards.

The paper is divided into three sections : the primary frequency standard, standard frequency emissions, and monitoring the standard frequency emissions.

The primary frequency standard consists of two independent groups of piezo oscillators. Section I consists of four piezo oscillators with frequencies of 100 kc/s. Section II has two piezo oscillators, one with a frequency of 100 kc/s and the other 200 kc/s, from which a 100 kc/s output is obtained by means of a submultiple generator. The absolute frequency of one of the units of each section is checked daily against the Arlington time signals by a synchronous motor clock driven by the 100th submultiple of the frequency of the controlling unit. Daily measurements provide a check on the frequency variations of the standard over an extended period. Frequency variations over short intervals are shown by an automatic recorder of the frequency difference between one of the units of section I and each of the other five units.

The National Bureau of Standards has transmitted standard frequencies from 1923 to date. Previous to 1931, a group of several frequencies was transmitted and a schedule of several groups announced. These emissions included frequencies from 75 to 10.000 kc/s. In 1931 5.000 kc/s emissions were started providing two-hour emissions, both day and night, every Tuesday. The transmitter is controlled by a 200 kc/s quartz plate kept at a constant temperature. These emissions have been successfully received and used for checking frequency standards throughout the United States. Measurements have been made and reported by several European countries, South America, and Australia. Measurements upon these emissions by the National Physical Laboratory of England show agreement between the two national standards to a part in ten million.

The emissions are monitored continuously at a distance of 20 kilometres in terms of one or more units of the national primary standard of frequency. The recieved frequency is compared with the 50th or 100th harmonic of the primary standard, which results in a frequency difference of 1 to 5 cycles per second. Frequency deviation smaller than a part in a hundred million can easily be measured (1).

No 43. — **A high frequency electrodynamic ammeter,** by H. M. Turner and P. C. Michel.

The object of this development is to providee an independent method of checking thermocouple instruments at frequencies up to one hundred megacycles and higher.

Description. — The ammeter may be thought of as a special type of air-cored transformer consisting of a vertically mounted, single turn, primary which carries the current to be measured and a smaller vertically suspended, closed turn or ring, secondary. The quartz suspension and secondary ring are shielded from external air currents by a glass tube terminating in a spherical bulb with provision for inserting the ring after which it is resealed. To prevent excessive damping of the ring during measurement there should be a clearance of at least one-half centimetre between it and the bulb.

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(1) To be published in the Bureau of Standards Journ. of Research.

Theory. — At high frequencies the primary and secondary currents are opposite in phase. The interaction of the resulting fields is such as to rotate the secondary into a position of zero coupling perpendicular to the plane of the primary where motion would cease were it not for the kinetic energy of the ring which carries it beyond where the direction of the torque is reversed and torsional oscillations occur about the vertical diameter of the secondary coil. The reaction of the secondary on the primary is negligible if its maximum departure from the perpendicular does not exceed ten degrees. The free period of the ring with zero primary current is forty seconds indicates a small suspension torque.

The unknow current, as determined by the ammeter, is independent of the wave form and frequency and its effective value is given by the equation

$$I = kF$$

where F is the mechanical frequency of torsional oscillation of the coil in the field of the current being measured. The constant k may be calculated from the physical dimensions of the ammeter circuit or measured at low frequencies, say one or two megacycles, with a thermo-ammeter of known accuracy.

N° 44. — **Exposé des recherches récentes sur les oscillations non linéaires,** par L. Mandelstam, N. Papalexi, A. Andronow, S. Chaikin et A. Witt.

Le rapport contient un exposé succinct des travaux sur les oscillations « non linéaires », effectués pendant ces dernières années par l'Institut de Physique de l'Université de Moscou, le Radio-Laboratoire Central, l'Institut d'Electrophysique de Léningrad et l'Université de Gorki. Ces travaux se rattachent à la théorie des systèmes non linéaires, basée sur les méthodes de Poincaré et Liapounov et traitent des sujets suivants : 1) Représentation géométrique de la conduite d'un système oscillant ; plan de phase ; points singuliers ; cycles limites de Poincaré. 2) Méthodes quantitatives approchées d'étude des systèmes non linéaires ; étude des équations « tronquées » de van der Pol. 3) Conduite du système en cas de variation d'un paramètre. Exemple : systèmes à excitation « douce » et « brusque ». 4) Systèmes autonomes: étude des systèmes donnant des oscillations de relaxation ; phénomènes oscillatoires discontinus ; conditions de discontinuité ; paramètres parasites ; cas où ils ont une importance essentielle dans les questions de stabilité ; systèmes auto-oscillatoires à paramètres distribués. 5) Action d'une force extérieure sur un système auto-oscillatoire ; synchronisation forcée en cas de fréquences voisines ou multiples ; analyse détaillée des phénomènes qui ont lieu dans le voisinage de la « bande de synchronisation » ; synchronisation forcée sur des fréquences « combinatoires ». 6) Phénomènes de résonance de n^{me} espèce (il s'agit de phénomènes de résonance qui se produisent dans un système non amorcé sous l'action d'une f. e. m. dont la fréquence est un multiple entier de sa fréquence propre) : théorie du phénomène et résultats expérimentaux pour la résonance de 2^{me} espèce ; possibilité d'utiliser le résonance de 2^{me} espèce pour combattre les brouillages atmosphériques (filtres sélectifs autoparamétriques) ; excitation asynchrone. 7) Excitation paramétrique : théorie de l'excitation d'oscillations sans f. e. m., par variation périodique des paramètres du système ; descriptions d'expériences dans lesquelles des oscillations sont excitées par variation périodique de la self-induction ou de la capacité d'un circuit (puissance utilisable : quleques KW dans le cas de la self-induction) ; oscillations forcées dans les systèmes à paramètres variables ; résonance généralisée dans les systèmes dont les paramètres varient périodiquement ; phénomènes de « regénération paramétrique » ; oscillations de systèmes couplés paramétriquement (pendule élastique, transformateur paramétrique). 9) Etude des phénomènes statiques qui ont lieu dans les systèmes dynamiques.

N° 45. — **Measurement of ionosphere layer heights and correlation with other geophysical and cosmic data,** by Prof. E. V. Appleton. — (Full text).

In the absence of data derived from measurements *in situ*, such as are possible for the lower strata of the atmosphere, information concerning the nature of the ionosphere (80 km and above) is derived from ground observations on (1) terrestrial magnetism (2), luminous manifestations such as the aurorae, meteorites etc., and (3) wireless wave exploration. Although the first indication of pronounced upper-atmosphere ionisation came from (1), the prosecution of (3) has proved, on the whole, the most fruitful. Wireless methods possess the marked advantage in that an exploration can be made at any time and it is not necessary to wait for natural sequences or irregularities.

Wireless exploration consists in projecting waves (usually) vertically upwards and noting the characteristics of the reflected energy. The quantities measurable are (*a*) the time of flight on the up and down journey (*b*) the polarisation and phase changes, and (*c*) the intensity of the returned waves. Each type of measurement has been made to yield information. From measurements of (*a*) at different wave-lengths the somewhat complicated structure of the ionosphere has been broadly worked out an its temporal variations studied. From (*b*) conclusive evidence has been derived that free electrons exist throughout the whole of the ionosphere and are the active electrical agents in causing the deviation of the waves, while from (*c*) the frictional effect of air pressure on the free electrons may be estimated.

Regular Features. — The ionosphere is divided into two main divisions. Region E at an equivalent height of 100 km. and Region F at an equivalent height of 250 km. and above. In both regions the ionisation is replenished daily at a rate dependent on solar altitude and during the night steadily decreases. (During the day a lower « shelf » is also formed on the mains Region F). The diurnal and seasonal variations are such as can be explained by assuming solar ultra-violet light as the ionising agency and recombination of electrons and ions as the dissipative influence.

Irregular Features. — (A) There is often formed a thin reflecting sheet of ionisation about the height of Region E. This may occur by day or night. Possible influences to be discussed in connection with the origin of this « abnormal Region E » are :

(1) Extraneous ionising agencies (e. g. solar corpuscles and terrestrial thunderstorms).

(2) Horizontal motion of ionisation from more densely ionised regions by winds or diffusion. The coefficient of lateral diffusion may be shown to be a maximum at about 100 km.

(3) Readjustment of ionisation already present due to tidal or thermal influence, bringing about a sharper gradient of refractive index at a particular level and thus giving rise to quasi-reflection as distinct from the normal deviating process.

(B) The maximum ionisation content in Region F is often found to increase during the night. Possible influences to be considered are:

(1) A nocturnal ionising agency.

(2) Readjustment of ionisation distribution due to cooling and shrinking of the atmosphere causing an increased electron concentration.

(C) Occasionally there are found subsidiary regions of ionisation (1) between Regions E and F, and (2) above the main Region F. These have been noted at both the Slough Radio Research Station and at the Halley Stewart Laboratory, Hampstead.

Suggestions for international co-operation. — It is suggested that, from the point of view of international exchange of data (URSI-grams, etc.) it is preferable to express the date in terms of critical penetration frequencies than in equivalent heigths of reflection. In this way it is possible to apply the method of measuring maximum ionisation densities previously described (1) and which has now been adopted in a number of participating countries.

N° 46. — **Report of the British National Committee to Commission II on investigations of the propagation of waves carried out in Great Britain from April 1931 to June 1934**, by R. L. Smith-Rose, National Physical Laboratory. — (Full text).

Investigations into the mode of propagation of electric waves over the earth's surface and through the ionosphere have been continued in Great Britain on an extensive scale during the past three years. Much of this work has been carried out under the auspices of the Radio Research Board established under the Department of Scientific and Industrial Research. In addition, members of the staffs of the British Post Office, the British Broadcasting Corporation and Marconi's Wireless Telegraph Company, Ltd., have described the results of their research on propagation problems where this was necessary in connection with their particular work on radio communication. Investigators at various Universities have also carried out work on some scientific aspects of the propagation of waves.

A summary of this work is conveniently divisible into the following sections :

(A) The radiation of waves from antennae.
(B) The propagation of waves along the ground and the effect thereon of the electrical constants of the earth.
(C) The propagation of waves through the upper atmosphere.
(D) The propagation of ultra-short waves through the lower atmosphere.
(E) The behaviour of direction-finding installations and the application of the results to propagation problems.

The following survey represents a very brief summary of this work under the above classification. A bibliography is attached to this Report giving direct references to the main papers which have been published in British Journals on the subject. Limitations of space have necessitated the omission of much subsidiary work, reference to which, however, will usually be found in the papers quoted.

A) The radiation of waves from antennae. — The modern development of antenna arrays for use in the directive systems of radio communication has drawn attention to the need for studying the mechanism of the radiation in the immediate neighbourhood of the aerial. One contribution to this subject made by J. A. Ratcliffe, L. G. Vedy and A. F. Wilkins (1) describes an experimental investigation of the variation with distance of the electric and magnetic fields in waves radiated from a source which approximates to a Hertzian dipole. On a wavelength of 1,000 m. the results were found to agree with theory at distances down to 0.01 λ from the aerial. The absorption and re-radiation of energy by a receiving aerial has also been studied by Ratcliffe (2) and, using long waves, agreement was obtained with the ordinary theory. The properties of an earthed receiving aerial with uniformly distributed constants has been investigated theoretically and experimentally by F. M. Colebrook (3). The theoretical formulae for the resistance and reactance of an aerial of any length were verified by experimental measurements for a typical case. The current distribution in a receiving aerial was shown to depend upon the distribution of the exciting field, and in some cases, to be totally different from the distribution in a transmitting aerial of the same height. Current nodes in a receiving aerial may be any distance apart from 0 to λ, and are not necessarily separated by half a wavelength as in a transmitting aerial with a point source of excitation. J. S. McPetrie (1) has extended his former work on the determination of the electric field in the neighbourhood of an aerial by taking into account the effect of the conductivity and dielectric constant of the earth. In the paper to which reference is made, a formula was deduced by means of which the field can be calculated at various distances from an aerial carrying a known current distribution.

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(1) *Nature*, Feb. 7, 1931, and *Proc. Roy. Soc. A.*, 137, pp. 36, 1932.

(1) J. A. Ratcliffe, L. G. Vedy and A. F. Wilkins, The Spreading of Electrogmatnetic Waves from a Hertzian Dipole. *Journ. Inst. Ing.*, 1932, vol 70, 522.

(2) J. A. Ratcliffe, The Absorption of Energy by a Wireless Aerial. *Proc. Camb. Phil. Soc.*, 1931, vol. 27, 588.

(3) F. M. Colebrook. An Experimental and Analytical Investigation of Earthed Receiving Aerials. *Journ. Inst. Elect. Eng.*, 1932, vol. 71, 235.

A considerable amount of research on and development of antenna arrays for long-distance beam communication has been carried out by the British Post Office, and the results obtained have been described in papers published by T. Walmsley (2). Particular attention has been paid to the economic advantages of a specially-devised array with horizontal radiations, and the losses in the associated transmission lines have been studied and reduced to the minimum.

Measurements have been made of the best angle of projection of beams of radiation for various point-to-point communication services, and arrays have been designed to emit the axis of the main lobe of radiation in this direction. The cost of array systems rises rapidly not only with increase in the wavelength, but also with an increase in the angle to the vertical at which the radio energy is required to be projected or received. A new type of directive array has also been devised (3), in which the dimensions of the radiators are graded to facilitate their matching at the various points of connection to the transmission line. The Marconi Company has cooperated with the Post Office in studying the polar distribution of energy in a beam at a considerable distance from the source. The results obtained have been described by T. L. Eckersley (1), who demonstrated the lateral deviation of the waves particularly when these cross the sunset boundary. It is considered probable that the explanation of this deviation if that there are horizontal as well as vertical gradients of ionisation in the portion of the atmosphere through which the waves travel. An antenna of cylindrical parabolic form has been developed and used by G. Marconi (2) in his work on the practical utilisation of very short waves of about 50 cm. wavelength. The increased application of wavelengths of a few metres has necessitated fresh investigation of certain problems in which the dimensions of the transmitting or receiving system was formerly assumed to be negligible compared with the wave-length. In this field, L. S. Palmer (3) has studied the action of frame aerials at wavelengths below 10 metres. When the length of side of such a frame approaches or exceeds half the wavelength, certain dimensions of the perimeter have to be obtained if the optimum conditions of reception are to be fulfilled. The similar problem of the action of a tuned rectangular frame when transmitting short waves has also been studied (4); and experiments have shown that a variation of the frame-dimensions affects both the frame current and the radiation (5) In the papers referred to, the author has given a theoretical explanation of the observed results.

B) THE PROPAGATION OF WAVES ALONG THE GROUND AND THE EFFECT THEREON OF THE ELECTRICAL CONSTANTS OF THE EARTH. — During the period under review, it appears that published work in this country on the effect of the ground on wave propagation has been confined to investigations conducted by the Radio Research Board. Amongst these, R. Naismith (¹) has described the results of an intensive survey of the field intensity in Devon and Cornwall of signals from the Daventry (5XX) transmitting station. The experimental measurements showed that abnormal wave attenuation effects were observed. The precise cause of these effects was not definitely located but may have been either the hilly nature of the country or the low conductivity of the ground, which is of a stony, granite or slate nature in that locality. The general study of the attenuation of waves over land, which has been described in previous reports, was extended to experimental work on wave-lengths of the order of 20 metres, an account of which has been published by G. H. Munro (²). For a series of measurements carried out on suitable sites in the South-East of England, the results show that at distances from the transmitter in excess of 2 miles, the decrease in field intensity was approximately proportional to the inverse square of the distance as would be expected from the theory of Sommerfeld. For shorter distances, however, the attenuation appeared to be much less than that predicted by theory, a result which was attributed to penetration of the waves to layers of greater conductivity below the surface. In all cases, marked changes in intensity and attenuation were found to occur with apparently slight changes in the nature of the surface and in the slope of the ground. On the much shorter wave-lengths of 1.6 m. the propagation of the waves along the ground has been studied by R. L. Smith-Rose and J. S. McPetrie (³), who have carried out relative field strength measurements at distances up to about 20 wave-lengths from the source. At such a short wave-length the heights above the ground of both transmitter and receiver exercise a large influence upon the received field intensity, and interference effects are experienced between the direct wave from transmitter to receiver and the indirect wave which arrives at the receiver after reflection from the surface of the ground. From a study of such interference curves the electrical constants of the ground can be deduced for the wave-length in use. For this purpose, McPetrie has improved upon the method by arranging the transmitter vertically above the receiver so that the reflection coefficient of the ground is measured for waves at normal incidence, and a recently published paper (¹) gives the results obtained in this manner at wave-lengths of 1.5 and 0.5 m. The values of conductivity and dielectric constant of the ground so deduced have been partially confirmed by laboratory measurements in the same wave-length range (²).

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(1) J. S. McPetrie. A Method for Determining the Effect of the Earth on the Radiation from Aerial Systems. *Journ. Inst. Elect. Eng.*, 1932, vol. 70, 382.

(2) T. Walmsley, An Investigation into the Factors controlling the Economic Design of Beam Arrays. *Journ. Inst. Elect. Eng.*, 1934, vol. 74, 543.

(3) T. Walmsley, A New Type of Directive Aerial. *Wireless Eng.*, 1932, vol. 9, 622.

(1) T. L. Eckerlsey, Experimental and Theoretical Study of the Polar Distribution of Energy in a Beam at Great Distance from the Sender. *Marconi Rev.*, n° 43, 1.

(2) G. Marconi, Radio Communication by Means of Very Short Electric Waves. *Proc. Roy. Inst.*, 1932, vol. 27, 509 and *World Radio*, 1932, vol. 15, 1314, 1346 and 1379.

(3) L. S. Palmer, On the Action of Tuned Rectangular Frames when Receiving Short Waves. *Proc. Roy. Soc.*, 1932, vol. 136, 193.

(4) L. S. Pamer and D. Taylor, The Action of a Tuned Rectangular Frame Aerial when transmitting Short Waves. *Proc. Phys. Soc.*, 1934, vol. 46, 62.

(5) L. S. Palmer, D. Taylor and R. Witty, The Current Distribution round a Short Wave Frame Aerial. *Proc. Phys. Soc.*, 1934, vol. 46, 76.

The propagation of electric waves to considerable distances over a semi-conducting spherical surface has been investigated recently by T. L. Eckersley (³), who has applied a phase integral method to obtain a suitable diffraction formula. This is an important advance on Watson's original diffraction formula which is only applicable to a perfectly conducting earth. In order to illustrate the effectiveness of the new formula, Eckerlsey has utilised the results of field intensity measurements made on the Warsaw broadcasting station (⁴), which is situated on a flat

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(¹) R. Naismith, Field Strengh Measurements on Daventry 5XX. *Journ. Inst. Elect. Eng.*, 1931, vol. 69, 881

(²) G. H. Munro, The Attenuation of Short Wireless Waves on the Surface of the Earth. *Journ. Inst. Elect. Eng.*, 1932, vol. 71, 135.

(³) R. L. Smith-Rose and J. S. MacPetrie, The Propagation along the Earth of Radio Waves on a Wave-length of 1.6 metre. *Proc. Phys. Soc.*, 1932, vol. 40.

(¹) J. S. McPetrie, A Determination of the Electrical Constants of the Earth's Surface at Wave-lengths of 1.5 and 0.46 m. *Proc. Phys. Soc.*, 1934, vol. 40.

(²) R. L. Smith-Rose and J. S. McPetrie, The Measurements of the Electrical Constants of Soil by a Lecher Wire Method at a Wave-length of 1.5 m. *Proc. Phys. Soc.*, 1934, 46.

(³) T. L. Eckersley, Radio Transmission Problems Treated by Phase Integral Methods. *Proc. Roy. Soc.*, 1932, vol. 136, 499.

(⁴) T. L. Eckersley, Note on the Field Intensity of the Marconi Broadcasting Station Erected at Warsaw. *Marconi Rev.*, 1932, nº 38, 20.

uniformly conducting site, and operates on a wave-length of 1400 m. The measured field intensities at distances from 100 to 500 kilometres are in good agreement with the values calculated theoretically on the basis of a ground conductivity of about 10^8 e. s. u. No such agreement could be obtained with either Watson's original diffraction formula, or with Sommerfeld's formula which takes into account the earth's conductivity. Confirmation of the accuracy of Eckersley's modified diffraction formula has also been obtained in measurements by the British Broadcasting Corporation of the field intensity of the Daventry broadcasting station at distances up to 700 kilometres. These results definitely support the view that diffraction is the controlling factor in long distance long wave (1,000 to 2,000 m.) daylight broadcasting.

C) THE PROPAGATION OF WAVES THROUGH THE UPPER ATMOSPHERE. — Investigations of the mode of propagation of electric waves through the electrified portions of the upper atmosphere, nowadays termed the ionosphere, have been continued on an extensive scale in England during the past three years. The majority of this work has been conducted under the auspices of the Radio Research Board by Professor E. V. Appleton (of the Halley-Stewart Laboratory), in cooperation with the staff of the National Physical Laboratory at Teddington and Slough. In addition to the work carried out in England, the above organisation equipped an expedition to Norway and conducted a detailed investigation of the propagation of waves in Northern Latitudes during the International Polar Year from August 1932 to August 1933. Other investigations on this subject have been made by Mr. J. A. Ratcliffe and his colleagues at the Cavendish Laboratory, Cambridge, and by Mr. T. L. Eckersley of the Marconi Company.

The results of all this work have been described in papers published in the Proceedings of the Royal Society, the Physical Society, the Cambridge Philosophical Society, and the Journal of the Institution of Electrical Engineers, while in addition a number of contributions have been made in the form of letters to Nature. A useful meeting was held at the Royal Society in June 1933 at which the present state of knowledge on the ionosphere was discussed by the leading investigators (¹), while in 1932 Professor Appleton summarised much of this own work on the subject in a lecture before the Institution of Electrical Engineers (²).

1. *Methods employed by the Radio Research Board.* — The method adopted by Appleton and the Radio Research Board's organisation in this investigation consists in sounding the ionosphere vertically above the observing station by projecting electric waves at approximately vertical incidence. The waves are modulated either in amplitude (as in the pulse method) or in frequency (as in the frequency-change method) and their return time of travel between the ground and the ionosphere yields a variety of information. The relative advantages of these two methods have been discussed by E. V. Appleton and G. Builder (³) in a paper, which also contains an account of a simple arrangement for producing the short pulses of radio frequency energy required of the first method. So far as actual accuracy is concerned there is little to choose between the two methods but when the downcoming waves are weak compared with the ground waves, the frequency-change method is found to be considerably more sensitive, and it is thus particularly suitable for carrying out experiments over a large range of wave-lengths. On the other hand the pulse possesses very great advantages when used under conditions in which multiple-echo signal are obtained. Also in the modern development of the experimental technique, involving the use of a cathode-ray oscillograph (⁴) with the

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(¹) E. V. APPLETON and others, Meeting for Discussion on the Ionosphere. *Proc. Roy. Soc. A.*, 1933, vol. 144, 697.

(²) E. V. APPLETON, Wireless Studies of the Ionosphere. *Journ. Inst. Elect. Eng.*, 1932, vol. 71, 642.

(³) E. V. APPLETON and G. BUILDER, Wireless Echoes of Short Delay. *Proc. Phys. Soc.*, 1932, vol. 44, 76.

(⁴) R. A. WATSON-WATT, J. F. HERD and L. H. BAINBRIDGE-BELL, The Cathode Ray Oscillograph in time-base synchronised with the emitting station, the pulse method facilitates the production of a quasi-stationary picture of the received signals, which is admirably suited for photographic registration. It has previously been shown on theoretical grounds that the two methods measure the same physical quantity, which is conveniently termed the equivalent height of the ionised layer at which the upgoing waves are returned to earth. Experimental confirmation of this point under a variety of conditions has more recently been provided by R. Naismith (1).

2. *General study of Ionosphere.* — As a result of investigations previously recorded, it has been shown that there exist in the upper atmosphere two main ionised regions from which electric waves are reflected. The lower of these is termed the Kennely-Heaviside Layer or E region, while the upper is now known as the Appleton Layer or F region. The latter has been shown to be richer in ionisation than the former, so that waves which penetrate the lower layer may still be reflected back to earth from the upper layer. As stated above, the majority of the work at present under discussion deals with the projection of waves vertically upwards from the earth into the atmosphere. It is reasonable to assume that reflection at vertical incidence on an ionised layer occurs at a place where the refractive index tends to zero. Then, since the expresion for the refractive index, in terms of the frequency of the waves and the ionisation density, is known, an observation of the lowest wave frequency which will just penetrate an ionised region will provide a measure of the ionisation density in the region in question. Experiments carried out on this basis have been described by Appleton and Naismith (1). Measurements of the equivalent height of reflection were made at approximately vertical incidence for a range of wave-lengths from 500 to 50 metres (frequencies 0.6 to 6.0 megacycles per second). It was found that at a certain critical frequency the equivalent height of the reflecting layer suddenly increased from a value of about 100 kilometres for the long waves to two or three times this amount for shorter waves, indicating that the point of reflection had changed from region E to region F at this critical frequency. This critical penetration frequency is found to vary diurnally and seasonally, and from measurements made in South-East England over a period of nearly two years (January 1931 to November 1932), the variation in the maximum ionisation content of the Kennelly-Heaviside layer has been studied in some detail (2). The value of this ionisation was found to be at a maximum about noon and at a minimum just before dawn. The diurnal variation curves were found to correspond very closely to the theoretical curves obtained by S. Chapman in his study of atmospheric ionisation produced by a solar stream of monochromatic radiation. Summer noon ionisation has been found to be 2.2 times as intense as Winter noon ionisation, the density of electrons per c. c. in the latter case being of the order of 1.8×10^5. It was also found that in 1932 the ionisation was somewhat less intense than in 1931, the reduction being attributed to the approach of a sunspot minimum. The diurnal variation curves definitely indicate that the chief agency responsible for the ionisation is of solar origin and travels through the atmosphere in straight lines, and observations carried out during recent solar eclipses lead to the conclusion that this agency is ultra-violet light. It is possbile, however, that thunderstorms

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Radio Research; published by H. M. Stationery Office, London, 1933.

(1) R. Naismith, A Comparison of the Frequency-change and Group-Retardation Methods of Measuring Ionised-Layer Equivalent Heights. *Proc. Phys. Soc.* 1932, vol. 45, 235.

(1) E. V. Appleton and R. Naismith, Measurements of Upper-Atmosphere Ionisation. *Proc. Roy. Soc. A.*, 1932, vol. 137, 36.

(2) E. V. Appleton and R. Naismith, Weekly Measurements of Upper-Atmosphere Ionisation. *Proc. Phys. Soc.*, 1933, vol. 45, 389.

constitue a subsidiary cause of upper-atmospheric ionisation as previously sugested by C. T. R. Wilson (¹).

In a manner similar to that described above, the ionisation of the upper layer or F region can be investigated by ascertaining the lowest frequency of waves which will just penetrate both regions at normal incidence. Experiments made in this manner have shown that the noon ionisation in Region F is nearly 4 times that in Region E, having a value of about 6×10^5 electrons per c.c. Neither the diurnal nor seasonal variation of Region F is as marked as that of Region E, the ratio of summer to winter day-time ionisation being about 1.5 to 1.8 for the former as against 2.2 in the latter case. The maximum of Region E ionisation is reached at a height of about 100 kilometres above the ground ; the height of the corresponding Region F maximum is much more difficult to estimate but is probably about 200 kilometres.

Working on somewhat similar lines to those described above, J. A. Ratcliffe and E. L. C. White (²) have developed at Cambridge, apparatus for the continuous automatic recording on a single frequency of the equivalent height of the ionised layer using a pulse emitter. Records taken on frequencies of 2 and 4 megacycles per second (wave-lengths 75 and 150 m) show that an abnormal increase of ionisation frequently occurs in the E region during the hours of darkness, without a corresponding increase in the upper of F Region. This is possibly due to the ionising action of storm clouds as already suggested by C. T. R. Wilson.

3. *Polarisation of Echo-Waves.* — During the investigations described above it was noticed on some of the records that the pulse echoes sometimes contained two components (³) differing slightly in their time of arrival and thus in the equivalent paths which they had pursued. This phenomenon was first observed several years before, using the frequency-change method, but it has since been studied in greater detail by the pulse method. Special receiving arrangements were devised to test the nature of the polarisation of the doublet-components and, as was surmised, it was found that these components represented arriving waves which were elliptically or circularly polarised in opposite senses, the component of lesser delay being in general of right-handed and the one of greater delay being of left-handed polarisation (¹). The diurnal study of this phenomenon has shown that a greater concentration of electrons is required to secure the return of the longer-delay component than is required for the component of shorter-delay. Each of these components may, after reflection from the earth, be returned from the ionised layer a second time, giving two additional echoes. No further splitting takes place, however, indicating that the polarisation of the incident waves is different from that of the waves incident on the layer at the first reflection; in fact the wave polarisations on the second incidence are such that the waves travel without change within the ionised medium. All these results are consistent with the magneto-ionic theory, which takes account of the earth's magnetic field on the passage of waves through the ionosphere. Except in certain special circumstances, the order of arrival of the components, as stated above, should prevail throughout the Northern Hemisphere. The predicted reversal of the order in the Southern Hemisphere has since been verified by investigations conducted by the Australian Radio Research Board (²). Quite recently, Appleton (³) has made use of measurements of

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(¹) See (1) p. 156.

(²) J. A. RATCLIFFE and E. L. C. WHITE, An Automatic Recording Method for Wireless Investigations of the Ionosphere. *Proc. Phys. Soc.*, 1933, vol. 45, 399.

(³) See (3), p. 156 and (2), p. 158.

(¹) See (4), p. 156 and E. V. APPLETON and G. BUILDER, The Ionosphere as a Doubly-Refracting Medium. *Proc. Phys. Soc.*, 1933. vol. 45, 208.

(²) E. V. APPLETON, Polarisation of Downcoming Wireless Waves in the Southern Hemisphere. *Nature*, 1931, vol. 128, 1017.

(³) E. V. APPLETON, Radio Exploration of the Ionosphere. *Nature*, 1934, vol. 133, 793.

the critical penetration frequencies of the two components polarised waves to estimate the intensity of the earth's magnetic field in the ionosphere, obtaining a value about 10 per cent less than its value at the ground.

A receiver of somewhat different type, which makes it possible to discriminate between the right and left-hand circularly polarised components, has been constructed and used by Ratcliffe and White (¹). This receiver was used to test several deductions from the magneto-ionic theory for a wave-length of 100 metres (frequency 3 megacycles per second). Magneto-ionic effects were found in both the E and F regions, and the results indicate that electrons are responsible for the deviation of the waves in both regions. The apparatus was also employed to investigate the downcoming waves from some British broadcasting stations (²). These waves were found in general to be elliptically polarised with a left-handed sense of rotation, a result which is in agreement with Appleton's magneto-ionic theory.

Observations have been made by F. W. G. White (³) on the diurnal variation of waves reflected from the ionosphere during early morning periods from about 0200 to 0900 G. M. T. In the course of this work it was found that double-component echoes were sometimes obtained from the E region on a wave-length of 100 metres. The two components were comparable in intensity for a very short period during the morning, but during the greater part of the day a single component only was obtained from this region.

4. *The Fine Structure of the Ionosphere.* — The next stage in the investigation was to explore the behaviour of the ionosphere with incident waves varying over a wide frequency-range. Observations have been made of the equivalent path pursued by the waves in their journey between the ground and the ionosphere for wave-lengths from 150 to 43 m (frequencies between 2 and 7 megacycles per second). In all these experiments it has been possible to separate on arrival at the receiver, the two polarised components in the waves and this has brought forth a considerable increase in our knowledge of the ionised regions from which the waves are returned. A first description of this type of work has been published by Appleton (¹), who shows that the results indicate the existence at certain times of maxima of ionisation density intermediate between the E and F regions. For daytime conditions, and more frequently in summer than in winter, evidence of the existence of a protuberance or « ledge » on region F is found, which most probably indicates that under direct solar influence this region is sometimes composite. Evidence of the existence of ionisation between regions E and F has also occasionally been obtained at noon; so that the whole ionospheric configuration may be regarded as a composite structure of four component regions termed E′, E″, F′, F″ at successively increasing equivalent heigths. From the point of view of practical radio communication it is generally sufficient to regard the ionosphere as divisible into two main regions, which are E′ and F″.

Additional experimental observations leading to the same general conclusions have been made by Ratcliffe and White (²) using a combination of the polarised wave discriminator and automatic recording apparatus previously described. Records made over a period of fourteen months, chiefly on the wave-lengths of 75 and

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(¹) J. A. Ratcliffe and E. L. C. White, The Effect of the Earth's Magnetic Field on the Propagation of Short Wireless Waves. *Phil. Mag.*, 1933, vol. 16, 125.

(²) J. A. Ratcliffe and F. W. G. White, The State of Polarisation of Downcoming Wireless Waves of Medium Length. *Phil. Mag.*, 1933, vol. 16, 423.

(³) F. W.G. White, The Diurnal Variation of the Intensity of Wireless Waves Reflected from the Ionosphere. *Proc. Phys. Soc.*, 1934, vol. 46, 91.

(¹) E. V. Appleton, Fine Structure of the Ionosphere. *Nature*, 1933, vol. 131, 872; and On Two Methods of Ionospheric Investigation. *Proc. Phys. Soc.*, 1933, vol. 45, 673.

(²) J. A. Ratcliffe and E. L. C. White, Fine-Structure of Ionosphere. *Nature*, 1933, vol. 131, 873 and Some Automatic Records of Wireless Waves Reflected from the Ionosphere. *Proc. Phys. Soc.*, 1934, vol. 46, 107.

150 metres (frequencies 4 and 2 megacycles per second), have generally confirmed the type of structure of the ionosphere depicted by Appleton; but in addition the results indicate the existence at night of a third ionisation maximum in the E region, at some 10 to 20 kilometres below the daytime position of the main E layer. This *e*-region, as it is termed, appears to be associated with the occurrence of magnetic disturbances or of thunderstorms.

Information on the maximum electron density in the atmosphere and on its seasonal variation is likely to be obtained by observations on very short waves. Attention has been directed by R. A. Watson Watt (¹) to the marked effect of winter conditions on the reception in England of signals transmitted on the Rome-Sardinia radiotelephone channel on wave-length of 9.8 and 10.06 metres. During the years 1931-1933, Wilkins' observations failed to give any trace of signals from these stations between mid-October and about the end of April, although regular reception was experienced during the summer periods. A sharp change from summer to winter condition was found to occur simultaneously in long wave polarisation phenomena.

5. *Automatic Emission and Recording.* — While, in the experimental work summarised above, photographic registration of the received waves was employed, the exploration of the effects obtained on different wave-lengths or frequencies was carried out by manual operation. It was found desirable to improve the technique of the measurements, first, by decreasing to the minimum the time occupied in making a measurement of equivalent height or ionisation density, and secondly, by operating continuously over a wide frequency change. To this end, equipment was developed by means of which the frequency of the source can be increased continuously over the working range while pulses are being emitted. At the same time the tuning of the receiver is varied so as to be constantly in tune with the arriving waves. By this means determinations can be made of the state of ionisation in the atmosphere vertically above the observer over a range of frequencies from to 1 and 6 megacycles per second (wave-lengths 300 to 50 metres) in a period of time of the order of two minutes. Such an equipment was used during the International Polar Year Programme in Norway, and a typical record obtained by this means has been published by Naismith (¹). Automatic recording apparatus is now in constant use at the Radio Research Station for the purpose of obtaining records suitable for a statistical study of the properties of the ionosphere under a variety of conditions.

6. *Observations during the Polar Year* 1932-33. — In connection with the International Polar Year 1932-33 a party of British workers under the auspices of the Radio Research Board made a series of wireless observations at Tromsö in Norway, using a sending station specially erected at a distance of about 20 kilometres. The main objective of this expedition was to obtain a comparison of ionospheric measurements in high latitudes with those previously obtained in the South-East of England. While a complete account of this particular work must await the reduction of the numerous observations recorded, a brief summary of certain results has already been published (²). In the first place a greater distinction was experienced in Norway between magnetically quiet and disturbed days than is the case in England, this obviously being due to the greater magnitude of the magnetic disturbances themselves and the consequent changes in ionisation. For undisturbed conditions there are usually the two reflecting regions which have been observed in England. While the normal daily maximum

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(¹) R. A. Watson-Watt, Winter in the Ionosphere. *Nature*, 1932, vol. 129, 761.

(¹) R. Naismith, Methods of Ionospheric Ionisation. *Nature*, 1934, vol. 133, 66.

(²) E. V. Appleton, R. Naismith and G. Builder. Ionospheric Investigations in High Latitudes. *Nature*. 1933, vol. 132, 340.

ionisation content is less in Norway than in England, the seasonal variation is greater. One of the most remarkable features of the results has been the frequent occurrence of disturbed conditions. During conditions of intense magnetic activity a complete cessation of echoes was found on all wave-lengths from 30 to 500 metres. This phenomenon cannot be due to electron limitation and is therefore to be attributed to absorption of the waves by the production of ionisation in the lower regions of the atmosphere. It is considered that in order to account for the wireless phenomena in high latitudes it will be necessary to take into account the influence of ionising charged particles, as well as the normal influence of ultra-violet light. (A more detailed report of the work of the British investigators on special radio problems during the International Polar Year is given elsewhere by Professor Appleton).

7. *Mathematical Investigations.* — It will have been appreciated that the trend of the work summarised above is to investigate in some detail the properties of that portion of the atmosphere known as the ionosphere with the aid of electric waves used as exploring agency. It has been shown that the propagation of waves through the ionosphere depends upon the density of ionisation and the strength of the earth's magnetic field, as well as upon the time of day and the frequency of the waves employed. A theoretical formula governing this mode of propagation has been developed by E. V. Appleton and D. R. Hartree. From this formula a comprehensive series of curves have been derived by Mary Taylor (¹) illustrating for various typical conditions and frequencies, the variation of refractive index of the medium with ionisation density in the presence of the earth's magnetic field. The calculations were made in the first case, assuming no absorption of energy in the medium, while in a second paper, the effect of energy dissipation by collisional friction was taken into account. This work shows that for elliptically polarised waves travelling through the ionosphere, the attenuation and absorption are, in general, greater for the right-handed component than for the left-handed, with the direction of the magnetic field appropriate for downcoming waves in the northern hemisphere. The dispersion curves which accompany the papers referred to above, may be used for the interpretation of propagation phenomena, and also for calculations of the reflection coefficient, attenuation and absorption in practical cases for the wave-lengths and collision-frequencies for which they have been constructed; they further illustrate the general type of phenomena which is to be expected at other wave-lengths and intermediate collision frequencies. The calculated values of attenuation and indices of refraction lead to the general conclusion that the lower boundary of the Kennelly-Heaviside layer must be sharp in the optical sense and that reflection of long waves occurs at this boundary at the same height, in general, as that of much shorter waves.

Further consideration has recently been given by C. G. Darwin (¹) to the theoretical formula determining the dispersion of waves in an ionised medium, and the results of this will entail a re-examination of the work described above. It appears to be necessary that a specific experimental test of the formula should be carried out as early as possible.

8. *Studies in Long-Distance Transmission.* — In addition to the detailed exploration of the ionosphere vertically above the observing station, a certain amount of study has taken place on the propagation of waves over long distances, which has an obvious application to practical radio communication. T. L. Eckers-

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(¹) Mary TAYLOR, The Appleton-Hartree Formula and Dispersion Curves for the Propagation of Electromagnetic Waves through an Ionised Medium in the Presence of an External Magnetic Field. Part. 1. Curves for zero Absorption. *Proc. Phys. Soc.*, 1933, vol. 45, 245. Part. 2. Curves with Collisional Friction. *Proc. Phys. Soc.*, 1934, vol. 46, 408.

(¹) C. G. DARWIN, Refraction of Ionised Media. *Nature*, 1934, vol. 133, 62.

ley has continued his investigations in short wave propagation within the range between 14 and 50 metres. A new technique for the measurements of signal echoes from facsimile records was developed, and used in conjunction with field intensity measurements made in England on long-distance transmissions. The results of two years measurements of this type, together with a discussion of their theoretical interpretation were contained in a paper published by Eckersley in 1932 (¹). The facsimile records disclose a series of several separated marks corresponding to the arrival by different paths of a single transmitted impulse. The differences of time can be determined with considerable accuracy and the angle of incidence of the waves, together with the effective height and ionisation density of the reflecting layer can on certain assumptions be deduced. Scattering is shown in many of the records and is particularly intense on a wave-length of 60 metres after sunset. As an example of the results obtained by this method of analysis, it may be stated that for transatlantic transmission on a wave-length of 22 metres, the equivalent height of the deflecting layer ranged from 286 to 360 kilometres, while the estimated ionisation densities vary diurnally in the range 4 to 10×10^5 electrons per c. c. The latter portion of Eckersley's paper, referred to above, is devoted to a somewhat detailed theoretical discussion in which an attempt is made to give a physical picture of the nature of short-wave propagation through the ionosphere. It is considered to be important that the scientific processes involved in this propagation should be clarly understood if appreciable progress is to be made in the general efficiency of long distance radio-communication.

One of the most important practical consequences of Eckersley's work is the deduction that high-angle rays are attenuated to a much greater extent than low-angle rays, and that, therefore, long-distance transmission is almost wholly effected by waves projected at only a small angle of elevation above the earth's surface. This result has been confirmed by Walmsley (¹), who carried out special experiments between England and America, in which the angle of projection of the beam could be varied. In this manner it was shown that for a wave-length of 21 metres, the angle of projection from England to give the strongest received signal in America had an average value of about 76°, measured from the vertical. Further tests carried out with other countries in different directions confirmed the deduction that there is usually an optimum angle for projection of the beam, and that this is in the region of 70° to 80°, although the best value may vary both diurnally and seasonally. With the aid of this information, Walmsley has prepared graphs illustrating the economic design of antenna arrays in order to give a satisfactory communication service along a particular channel.

Working in the opposite direction, A. F. Wilkins (²) has measured the angle of incidence in England of waves emanating from stations near New York on wave-lengths in the region of 20 metres. The method adopted employed two similar horizontal aerials erected at the same height above the ground and at a distance apart of 2 wave-lengths. These aerials were connected through transmission lines and amplifiers to the deflecting plates of a cathode ray oscillograph, and from the resulting trace on the fluorescent screen, the phase difference of the e. m. f.'s in the aerials, and thus the angle of the arriving waves could be deduced. The results obtained in this manner showed that during the first four months of 1933, one main ray was in general received in England, accompanied by other rays of smaller amplitude : the average angle of incidence of this main ray was

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(¹) T. L. Eckersley, Studies in Radio Transmission. *Journ. Inst. Elect. Eng.*, 1932, vol. 71, 405.

(¹) See (2). p. 154.

(²) A. F. Wilkins, Measurements of the Angle of Incidence at the Ground of Downcoming Short Waves from the Ionosphere. *Journ. Elect. Eng.*, 1934, vol. 74. 582.

72° and was reasonably constant. Towards the end of April, however, it was found that the angle of incidence increased from the above value at noon G. M. T. towards a value of 85° or 90° as sunset approached; this change was accompanied by a decrease in average field intensity. These changes are attributed to an increase in ionisation with a resultant decrease in the effective height of the F region at which reflection takes place on these wave-lengths, while the fall in signal strength is probably due to the increase in absorption of the waves in their return passage through the lower E layer.

J. Hollingworth (¹) found that the angle of incidence in England of the main ray from a station at Moscow working on a wave-length of 50 metres was in the neighbourhood of 30°. These measurements were made by comparing the e. m. f.'s induced in a loop and in a vertical aerial, and observations made over a short period indicated that only on comparatively rare occasions did the angle stated above increase to values of 45° or 60°. The nature of the variations in intensity and state of polarisation of the arriving waves was demonstrated in Hollingworth's experiments and these suggest that further data are required before an explanation of the observed effects in terms of magneto-ionic theory is pressed too far.

D) THE PROPAGATION OF ULTRA SHORT WAVES THROUGH THE LOWER ATMOSPHERE. — Experimental investigations carried out during the past few years have demonstrated the utility of ultra-short waves within the band 1-10 metres for commercial radio communication. There are several examples in different parts of the world of the satisfactory use of radio-telephone links on wave-lengths within the above range. In many of these cases, it has been demonstrated that the distance of communication exceeds that for which the transmitter and receiver have an unobstructed straight optical path between them. For example, G. Marconi (¹) has shown that on a wave-length of 57 cms. communication was possible in the Mediterranean over distances approaching twice that of the optical range, and similar results have been obtained by other workers on wave-lengths up to 8 metres. In some of these cases, marked fading of the signal was observed particularly near or after sunset.

As far as available experimental evidence indicates, waves shorter in length than about 9 metres are not reflected from the ionosphere. Indeed, the observations of A. F. Wilkins, cited by R. A. Watson Watt (²) definitely indicate that wave-lengths of 9.8 and 10.06 used over a certain route may be reflected in the summer but not in the winter, when the electron density in the upper atmosphere never reaches a sufficiently high value to deflect these waves back to earth. The actual wave-length at which this effect of electron limitation becomes operative may naturally vary in different parts of the world.

From such considerations it appears likely, therefore, that the explanation of the propagation phenomena observed on wave-lengths below 8 or 9 metres is to be sought much nearer the earth's surface.

Some aspects of the problem of the refraction of electric waves in the lower atmosphere due to the variation of density of the air with altitude have been considered by R. L. Smith-Rose and J. S. McPetrie (³). As a result of this refraction the path of waves between a transmiter and receiver is curved in a manner concave to the earth's surface. For average atmospheric conditions the radius of curvature of this path is about six times the radius of the earth, and this will account for a considerable increase in the range obtainable over that which is limited to the straight line path tangential to the earth's

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(¹) J. HOLLINGWORTH, Some Characteristics of Short Wave Propagation. *Journ. Inst. Elect. Eng.*, 1933, vol. 72, 229.

(¹) See (2), p. 154.

(²) See (1), p. 160.

(³) R. L. SMITH-ROSE and J. S. MCPETRIE, Ultra Short Radio Waves. Refraction in the Lower Atmosphere. *Wireless Eng.*, 1934, vol. 11, 3.

surface. In both cases, naturally, the range is increased by raising the transmitter or receiver above the ground level. As a result of calculations made on these lines, it appears that the curvature of the waves by refraction is insufficient to account for some of the experimental ranges which have been obtained. The phenomenon of fading, however, is explicable as the result of convection currents in the air causing a variation of refractive index. In addition to these refraction effects, it is possible that diffraction around the curvature of the earth may contribute towards the propagation of ultra-short waves; although it appears likely on general grounds that diffraction effects will decrease as the wave-length is reduced, whereas the reverse is true for refraction. The problem of the diffraction of ultra-short waves requires further investigation, possibly on the lines adopted by T. L. Eckersley (1) for longer waves.

E) THE BEHAVIOUR OF DIRECTION-FINDING INSTALLATIONS AND THE APPLICATION OF THE RESULTS TO PROPAGATION PROBLEMS. — The progress which radio direction-finding has made in Great Britain during the past three years has largely been in the direction of increased instrumental accuracy. This work has not materially contributed to our knowledge of the mode of propagation of waves; rather has it been a case of making use of the main well-known facts in order to eliminate errors which result from the vagaries of such wave propagation. The basic principles of the Adcock or spaced-aerial direction finder were well-established some years ago and the recent work of the Radio Research Board has been aimed at the practical realisation of an instrument embodying these principles, and consequently immune from errors which are associated with closed loop direction finders under certain conditions of reception from the ionosphere. Detailed calculations of the conditions under which the Adcock system is liable to error or to give indefinite indications have been made by J. F. Coales (1). The application of the cathode-ray oscillograph to the radio direction finder is fully described in the work (2) published by R. A. Watson Watt, J. F. Herd and L. H. Bainbridge-Bell, to which reference has already been made in this report. In this book will be found also the application of the pulse transmitter to direction finding problems; first, as an alternative means of avoiding the errors of bearing indication due to downcoming waves; and secondly, as a rapid and accurate short-range indicator on board a ship, of the location of other ships in a fog, and hence providing the means by which a collision may be avoided. T. L. Eckersley (3) has also described the use of a pulse transmitter with oscillographic indication on a direction finder of the Bellini-Tosi type to give freedom from the errors accompanying the reception of downcoming waves.

When a radio direction finder is used on board a ship, it is necessary to take special precautions to reduce to the minimum the errors in bearing which result from the currents induced by the arriving waves in the metal work of the ship. Much detailed work in the special application to steel ships has been carried out by C. E. Horton (4) at H. M. Signal School, Portsmouth. Although by giving close attention to such matters as the placing of the direction-finding aerial system and the insulation of mast stays, a considerable improvement in performance can be obtained,it is still necessary for accurate working, to calibrate the ship's direction-finder after installation. An improved radio direction finder with accurate sense-indication has also been described by

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(1) See (3), p. 155.

(1) J. F. COALES, A Note on the Theory of Night Errors in Adcock Direction-finding Systems. *Journ. Inst. Elect. Eng.*, 1932, vol. 71, 497.

(2) See (4), p. 156.

(3) T. L. ECKERSLEY, Elimination of Night Effect with a Pulse Transmitter. *Marconi Review*, 1934, nº 46, 12.

(4) C. E. HORTON, The Practical Correction of a Wireless Direction-finder for Deviations due to the Metalwork of a Ship. *Journ. Inst. Elec. Eng.*, 1931, vol. 69, 623 and G. SHEARING, same subject, *Journ. Inst. Elect. Eng.*, 1934, vol. 74, 19.

C. E. Horton and C. Crampton (¹). This instrument utilises a combination of the figure-of-eight characteristic of a loop aerial and the cardioid characteristic obtained from a second loop in conjunction with a vertical aerial. The main advantage of this new system is the saving in time which is effected by the determination of bearing and sense in a single operation. The conditions necessary to secure the reliable working of the installation in a steel ship have been determined and it has been shown that the accuracy is similar to that obtained with the ordinary direction-finder which has the 180° ambiguity in its indications.

Observations taken with a cathode-ray direction-finder installed on a ship during a voyage from England to Australia have been described in a paper by G. H. Munro and L. G. H. Huxley (²). Directional observations of long wave transmitting stations at distances of 1,000 to 5,000 miles showed little evidence of errors in bearings, and the results were used to obtain the quadrantal error of the ship. With the aid of this information, systematic bearing observations on atmospherics were carried out during the voyage with a view to locating the chief sources of origin of these disturbances. J. A. Ratcliffe and J. L. Pawsey (³) have also made use of a direction finder of the Adcock or spaced-aerial type to investigate the possibility of the lateral deviation of waves out of the great circle plane through transmitter and receiver. Working on the medium broadcasting band of wave-lengths deviations of as much as 50° were sometimes obtained in the apparent direction of arrival of the waves. While these results need confirmation they afford an indication of the possibility of scattering, on comparatively rare occasions, of medium waves from the ionosphere in a manner similar to that experienced by Eckersley on short wave-lengths.

July 1934.

N° 47. — **The non linear theory of electric oscillations,** by Dr. B. van der Pol.

The paper gives a very extensive summary of the theory of non linear oscillations, i. e. the maintenance of oscillations in systems possessing a negative non linear resistance, and explains on this basis most of the oscillation phenomena obtained with oscillating thermionic tubes. It treats the following equations

(*a*) *Triode oscillator with one degree of freedom*:

$$v'' - \alpha\,(1 - v)v' + \omega^2 v = 0 \quad (\varepsilon = \alpha/\omega \ll 1)$$

(*b*) *Same as before, but with two terms more in the approximation to the characteristic* :

$$v'' - \alpha\,(1 - v^2 - \varepsilon_2 v^4)\,v' + \omega^2 v = 0 \quad (\varepsilon = \alpha/\omega \ll 1)$$

(*c*) *Triode oscillator with two degrees of freedom (coupled circuits)* :

$$\left\{\begin{array}{l} v_1'' - \alpha_1(1 - v^2{}_1)v'{}_1 + \omega^2{}_1 v_1 + k_1\,\omega^2{}_1\,v_2 = 0, \\ \hfill (\varepsilon_1 = \alpha_1/\omega_1 \ll 1) \\ v_2'' + \alpha_2 v_2' + \omega^2{}_2 v_2 + k_2\,\omega^2{}_2\,v_3 = 0 \\ \hfill (\varepsilon_2 = \alpha_2/\omega_2 \ll 1) \end{array}\right.$$

(*d*) *Triode oscillator with external electromotive force* :

$$v'' - \alpha\,(1 - v^2)v' + \omega^2{}_0 v = \omega^2{}_1\,\mathrm{E} \sin \omega_1 t. \quad (\varepsilon = \alpha/\omega \ll 1)$$

(*e*) *Free relaxation oscillations* :

$$v'' - \alpha\,(1 - v)\,v' + \omega^2\,v = 0 \quad (\varepsilon = \alpha/\omega \gg 1)$$

(*f*) *Relaxation oscillator with impressed E. M. F. (frequency demultiplication)* :

$$v'' - \alpha\,(1 - v)v' + \omega^2{}_0\,v = \omega^2{}_1\,\mathrm{E} \sin n\,\omega_1 t \qquad \left\{\begin{array}{l} \varepsilon = \alpha/\omega \gg 1 \\ \omega^2{}_1 \approx \omega^2{}_0 \end{array}\right\} \quad (^1)$$

(¹) C. E. Horton and C. Crampton, A Radio Compass Developed in H. M. Signal School. *Journ. Inst. Elect. Eng.*, 1933, vol. 73, 284.

(²) G. H. Munro and L. G. H. Huxley, Shipboard Obsrvations with a Cathode-Ray Direction-finder between England and Australia. *Jour. Inst. Elect. Eng.*, 1932, vol. 71, 488.

(³) J. A. Ratcliffe and J. M. Pawsey, A Study of the Intensity Variations of Domwncoming Wireless Waves. *Proc. Camb. Phil. Soc.*, 1933, vol. 29, 301.

(¹) *Proc. Inst. Rad. Eng.*, 22, 1051, 1934.

N° 48. — **Intercomparison of frequency standards by means of a modulated radio wave,** by Kiyoshi Takatsu, Keikitirō Tani and Yuzirō Kusunose.

During the period between February 7-9, 1934, the Radio Research Committee of the National Reserach Council of Japan carried out comparisons of the frequency standards maintained independently at the Electrotechnical Laboratory, the Naval Technical Research-Department, the Military Scientific Laboratory, and the Iwatsuki Radio Receiving Station. The experiment was made by simultaneously measuring the modulation frequency of a radio wave transmitted from the Electrotechnical Laboratory. The values of the modulation frequency measured by each laboratory agreed well, within 0.001 % (¹).

N° 49. — **Observations effectuées le 14 Mars 1934 de 01,45 à 03,40** (T. M. G.), par B. Decaux et J. B. Galle.

Ces observations ont mis en évidence que la différence de durée du trajet des ondes reçues en un même point et émises par deux stations de longueurs d'onde différentes ne restait pas constante mais variait d'un instant à l'autre.

Les deux stations émettrices : Daventry (fréquence 200 kc/s) et Londres Régional (fréquence 877 kc/s) étaient modulées simultanément par le diapason du National Physical Laboratory à la fréquence de 1000 cycles/sec. Les deux récepteurs à amplification directe utilisés au Laboratoire National de Radioélectricité à Paris, munis de dispositifs d'anti-évanouissement actionnaient chacun une des paires de plaques d'un oscillographe cathodique.

L'interférence des deux courants à 1000 périodes fournis par les deux récepteurs donnait une figure de Lissajou qui était une ellipse.

Cette ellipse est demeurée très stable de 02 h. 00 m. à 02 h. 03 m. Puis en 40 secondes, cette ellipse est passée d'un quadrant à l'autre (variation de phase des deux signaux) et se réduisait parfois à une droite dans l'un ou l'autre des quadrants (signaux en phase ou en opposition de phase).

Nouvelle période de stabilité de l'ellipse de 02 h. 04 m. à 02 h. 20 m. De 02 h. 20 m. à 02 h. 51 m. : variations très lentes de phase, l'ellipse se transformant en un cercle (quadrature) ou en une droite.

De 02 h. 51 m. à 03 h. 30 m. l'ellipse se déforme sans arrêt et très rapidement ; la phase varie de 180° en moins de 10 secondes. A certains moments la figure de Lissajou se transforme en une courbe en forme de huit caractéristique de l'intervalle d'octave. Ceci se produit en même temps que la réception de Londres Régional est très affaiblie et s'explique en admettant que l'onde porteuse n'est plus reçue alors que les deux bandes latérales persistent et se composent pour donner la fréquence double : c'est là une manifestation du « fading sélectif ».

N° 50. — **Report to Commission I on existing methods of measuring radio field intensity,** by R.A. Watson-Watt and R. L. Smith-Rose, National Physical Laboratory. — (Full text).

1. Object and Scope of Report. — At the general meeting of Commission I of the Union Radio Scientifique Internationale in Copenhagen in 1931, it was agreed that information should be collected relating to methods of measuring the intensity of electric fields at radio frequencies, and the work of co-ordination was allocated to the British National Committee. The British Radio Research Board undertook the responsibility for carrying out this work and assigned it to the Radio Department of the National Physical Laboratory. A detailed questionnaire (¹) was accordingly prepared and circulated to the various National Secretaries of the U. R. S. I. organisation for distribution

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(¹) *Report. Radio Res. Japan*, vol. IV, n° 2, 1934.

(¹) A Copy of this questionnaire was attached to the Report by Dr. E. H. Rayner on the work of Commission I since the Session in Copenhagen in 1931. See p. 131.

among the firms, institutions and individuals interested in the subject of field-strength measurement. Nearly 40 replies have been received to this questionnaire from representatives in 10 different countries. In many cases the replies were accompanied by reprints of published papers and unpublished reports describing special apparatus and the results of experiments made therewith. A tabular summary of the information obtained from the direct answers to the questionnaire is given in Appendix I (1), while the following sections of this report describe the results of an examination of all the replies received. A bibliography of the literature on the subject is given in Appendix II (2). The scope of the work throughout has been limited to a study of methods of measuring radiated field intensity, the application of such methods to the investigation of wave propagation and similar problems being excluded.

2. DEFINITION OF FIELD INTENSITY. — The field intensity in a simple electric wave may be defined as the R. M. S. value of the electromotive force induced in unit length of a conductor set parallel to the electric force in the wave. In certain cases for the study of wave propagation, particularly at short wave-lengths, it is necessary to refer to the field intensity in a horizontal or other direction and at heights above the earth's surface comparable with or greater than the wave-length. It is customary, however, in radio communication on all but the shortest wave-lengths, to limit the above definition to the field at or very near to the earth's surface and to the vertical component of the field in the plane of propagation of the waves. The practical unit employed in such cases is the volt per metre (conveniently divisible into millivolts per metre and microvolts per metre when required), implying that each metre of vertical aerial will have an e. m. f. of one volt induced in it by the arriving waves. The practical measurement of the electromotive force induced in an aerial rests, directly or indirectly, upon an observation of the current flowing in it, and as is well-known, the distribution of this current depends upon the wave-length employed, the dimensions and shape of the aerial, and on its surroundings. When an aerial is used for transmission or reception, the current is usually measured at a point in the aerial where it is a maximum and the current distribution is taken account of by the introduction of a term called the effective height of the aerial. Thus the electromotive force induced in the aerial may be considered to be the product of the electric force of the wave and the effective height of the aerial. Owing to the difficulty of precise determination of the effective height of an aerial it has become the general practice not to use an open aerial for the measurement of field intensity where it can be avoided. The replies to the questionnaire under consideration have shown that in the majority of cases, a closed frame coil is used as the receiving aerial in field strength measurements. Where an open aerial has been required, chiefly to obtain greater sensitivity, it is the practice to calibrate the aerial under the conditions of the measurement with the aid of a closed loop and a local oscillator or transmitter.

When a closed loop is set up in a vertical plane in the path of waves whose electric force lies in the vertical plane of propagation, the electromotive force induced in the loop (assumed small compared with the wave-length) is :

$$e = \mathrm{E\,A.\,N.}\,\frac{2\pi}{\lambda}$$

where :

E is the field intensity of the wave
A is the aerea enclosed by the loop
N is the number of turns on the loop
λ is the wave-length employed.

This value of the electromotive force is independent of the direction of propagation of the waves as long as this lies in the vertical plane of the loop. When the loop is placed near the earth's surface and the waves are travelling horizontally, E is the value of the vertical force in the passing waves. For any other direction of propagation in the vertical plane the above electromotive force must be supplemented by that induced by the corresponding waves reflected from the earth's surface. For the simpler case in which the waves are travelling horizontally, the above formula may be compared with that appropriate to a vertical aerial, viz.

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(1) P. 174. (2) P. 180.

$$e = \mathrm{E}h$$

in which « h » is the effective height of the aerial. From these two formulae we deduce a quantity which for practical purposes is termed the effective height of the loop given by the expression :

$$h = \mathrm{A. N.} \frac{2\pi}{\lambda}$$

If the dimensions of the loop and the wave-length are all given in metres, the value of « h » will also be expressed in metres.

The problem of field strength measurement thus resolves itself into the determination of the electromotive force induced by the arriving waves in a vertical, plane loop, the effective height of which is calculated from its dimensions and number of turns. This basis for the specification of field strengths is now established by universal practice in all countries, and it remains to consider the various methods which have been developed for the measurement of the electrical quantities involved.

It is the experience of many investigators that the use of closed loops becomes somewhat inconvenient, owing to the small pick-up factor attainable with a loop when the wave-length is reduced below the order of 20 or 30 metres. For such short waves a straight dipole antenna used in the vertical or horizontal position is probably more suitable for measuring the field intensity. It would be desirable to obtain some agreement on this matter, together with a specification of the antenna, including its dimensions, height above ground and the direction in which it should be used.

The above definition and statement of the fundamental theory of field intensity measurements are strictly confined to the case of a single plane polarised electric wave propagated horizontally. Such an ideal case is only encountered in practice in comparatively rare circumstances. In general, there may be present at the receiver, two or more waves which have travelled from the transmitter by different paths. These waves may be plane, circularly or elliptically polarised, the plane of polarisation may be rotated to any degree out of the vertical plane of propagation, and those waves which have travelled through the ionosphere may arrive at almost any angle of incidence. They may, moreover, have been deviated laterally from the plane of propagation. In such circumstances it must be realised that the simple field intensity as defined and measured on the basis outlined above, may differ considerably from the effective field intensity which is operative on the receiving aerial in practical communication. The specification of the field in terms of the e. m. f. induced in a closed loop gives the sum of the r. m. s. values of all the electric fields arriving in the plane of the loop. The practical receiving engineer may require to know the sum of the vertical or horizontal components of this field, and in the latter case the desired component may be at right angles to the plane of propagation. In the case of rapidly varying fields, as in fading conditions, he may desire a specification of the field intensity which is maintained over a selected percentage of the total (long) sampling period.

3. METHODS OF MEASURING FIELD INTENSITY. — (*a*) *Analysis of Methods in use.* — Except in one or two cases where special apparatus has been developed for research purposes, the field intensity has been determined by ascertaining the electromotive force which it is necessary to inject from a local generator into the receiving loop or antenna in order to give the same deflection on the indicating instrument as that produced by the arriving waves. In this connection, mention may be made here of a subsidiary but somewhat important practical advan-

tage which the loop possesses over the open antenna, viz., that, in the reception of vertically polarised waves, the loop may be rotated to a position in which the incoming signals give no indication while the set is being calibrated from the local source. This avoids the necessity of any special arrangements with the transmitting station for the interruption of signals for calibration purposes. This advantage is naturally not obtained in the not infrequent cases in which an appreciable proportion of the incoming radiation is horizontally polarised.

As to the means employed for carrying out this calibration, 15 of the respondents ot the questionnaire make use of apparatus based in all essential details upon the method developed in the Bell Telephone Laboratories and described in a series of papers published from 1923 onwards by Messrs. R. Bown, E. Bruce, C. R. Englund and H. T. Friis (See Appendix II (1). Commercial apparatus incorporating this method has been developed by the Western Electric Company in the U. S. A. as type N° 44A, and by the Standard Telephones and Cables Company in Europe. Amongst the other commercially developed apparatus, the most prominent in use are the sets produced by Marconi's Wireless Telegraph Co. Ltd., and the Radio Corporation of America. The former is known as Marconi Type 205 Field Strength Measuring Equipment and has been described in papers published in 1925 and 1929 by Messrs. H. J. Round and T. L. Eckersley; while the latter is known as Type TMV 21 based upon the method described by Messrs. H. H. Beverage and H. O. Petersen in 1923. The remaining respondents have employed apparatus, which was frequently designed and constructed by themselves for their own investigations and which makes use of a variant of one of the systems referred to above. In some cases automatic recording mechanism has been added to the apparatus so that continuous records of the field strength can be made over appreciable periods for the study of fading, etc.

A brief description of the chief systems in use with comments upon experiments made to determine the absolute accuracy of the equipment for the measurement of radio field intensities is given in the following sections.

As a general comment upon these methods, it may be stated that it appears to be necessary to satisfy certain fundamental conditions in order to ensure accuracy in measuring the desired quantity. In the first place, the e. m. f. induced in the loop should be solely due to the field in the arriving waves, i. e. the secondary field due to currents induced in neighbouring conductors by the arriving waves should be of negligible magnitude at the space occupied by the loop. This implies that the receiving loop must be a a sufficient distance from all metalwork, especially that of the receiving apparatus itself, to be immune from the action of the secondary fields. Next, the field intensity measurement assumes an accurate means of producing locally an electromotive force at radio frequency. If this frequency is that of the incoming waves, the accuracy of current and attenuation measurement at the signal frequency are brought into account. The use of resistance attenuators at high frequencies is considered by some investigators to lead to uncertainty in determination and in one method, this has been avoided by transferring the attenuator to the intermediate frequency stages of the amplifier, a transfer which also simplifies the problem of screening the comparison-oscillator. In other methods a variable mutual inductance coupling is employed as the attenuating device, and in this case it is possible that uncertainty may arise due, amongst other causes, to capacitive coupling between the coils. In the capacitance type of attenuator, care must be taken at high frequencies or with large capacitances that the residual inductance of the connecting leads does not involve an appreciable error in the calibrating system.

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(1) P. 180.

(*b*) *The Western Electric and Standard Telephones Field Strength Measuring Sets.* — As originally described by Messrs. Friis and Bruce, the Western Electric Field-strength measuring set comprises a loop aerial with a supersonic heterodyne receiver and a calibrated signal generator, and is suitable for use on all frequencies up to 40 megacycles per second. The signal indicating instrument is a microammeter connected in the anode circuit of the second detector valve. The magnitude of the locally-generated electromotive-force is obtained by passing a known current through a known impedance inserted at the centre of the loop. In order to avoid spurious errors due to « antenna effect » and to direct pick-up of local and incoming signals, the centre point of the loop is connected to earth, and the whole of the receiver and the calibrating oscillator are separately and adequately shielded. The deflection of the indicating instrument due to the local signal is adjusted to equal that caused by the incoming signal by the introduction of an attenuator in the intermediate frequency portion of the amplifier, this frequency being generally about 80 kc/s., but varying from 55 to 300 kc/s. in individual sets. The sensitivity of this method appears to vary somewhat with individual sets and with the frequency range employed but there appears to be no difficulty in covering field strengths between limits of about 0.2 microvolt per metre and 7 volts per metre. While the method has been primarly developed for measurements on continuous waves or on sound-modulated continuous waves, the apparatus has been adapted to measurements on signal transmissions and also on the noise level due to atmospheric disturbances.

(*c*) *The Marconi Field-Strength Measuring Equipment.* — The Marconi Field-Strength Measuring equipment has a frequency range of 25 Mc/s to 15 kc/s (wave-lengths 12 to 20,000 m.), while portable equipment has been more recently developed for the range 25 Mc/s to 150 kc/s. A tuned receiving loop is employed and precautions are taken to ensure symmetry of the loop and adequate shielding of the receiver, which is of the supersonic heterodyne type. For calibration purposes the output of the local oscillator is attenuated at the signal frequency by a resistance network and applied to the receiving loop through a calibrated mutual inductance. The application of the equipment appears to be chiefly for continuous waves, although presumably it could be adapted for the measurement of interrupted signals and atmospheric noise level in the same manner as the apparatus previsouly described. The sensitivity of the commercial equipment is such as to enable a range of field-strengths from 3 microvolts per metre to 3 volts per metre to be covered.

(*d*) *The R. C. A. Equipment.* — The equipment described by Messrs. Beverage and Petersen and developed by R. C. A. Communications Incorporated, uses either a loop aerial or a « condenser » antenna, i. e. a low flat-topped antenna for which the effective height is assumed to be equal to the actual height. The receiver and signal generator cover a frequency range of from 15 to 30,000 kc/s. In one set of apparatus a mutual inductance attenuator is employed to calibrate the set from the local generator, but the use of a screened resistance attenuator at the signal frequency appears to be more usual.

The R. C. A. Victor Company's Field Intensity Meter (type TMV 21) comprises a supersonic-heterodyne receiver with the second detector operating as a valve voltmeter; a loop antenna is used with means of inserting known values of resistance therein, and a comparison oscillator, the output voltage of which can be adjusted by means of a resistance attenuator. The frequency range of the apparatus is 550 to 4,500 kc/s. and the sensitivity covers the range 20 microvolts per metre to 3 volts per metre. This equipment has been largely used in Canada and the U. S. A. for determining the service area of broadcasting stations, and in this case unmodulated continuous waves are usually employed.

(*e*) *Methods using capacitance potential divider.* — Amongst the other methods, of which descriptions have been submitted, it is interesting to note that M. von Ardenne has developed a capacitance potential divider which has been used in some cases. This provides a method of subdividing the calibrating signal voltage to the desired extent, with freedom from frequency error at all but very high frequencies. A similar arrangement has also previously been employed by the workers at the Cavendish Laboratory, Cambridge.

4. USE AND COMPARISON OF THE DIFFERENT METHODS. — (*a*) *General Requirements.* — The objectives of those using radio field-strength measuring equipment vary considerably although they are eventually concerned, directly or indirectly, with the maintenance and development of radio communication. The large traffic-carrying organisations utilise such apparatus for the establishment and maintenance of new radio communication channels, as well as for the development of antenna arrays and transmitting and receiving apparatus; those responsible for the provision of broadcasting services need measuring equipment for determining the service area and interference range of broadcasting stations; the authorities controlling the purchase and installation of radio station equipment require apparatus for checking the output against the specification with which it is to comply; finally, but by no means least, field-strength measuring equipment is utilised by communication engineers and by physicists with more academic interests, for studying the propagation of radio waves both over the earth's surface and through the atmosphere.

In considering the use of field-strength measuring equipment for most of the above purposes, it is obviously desirable to know to what extent different sets of apparatus, particularly those in use in different parts of the world, are measuring the same quantity, and one of the objects of the U. R. S. I. questionnaire was to ascertain the nature and extent of any comparisons which had been made in this field, and what agreement was obtained in this work. In answer to a direct question on the subject, the respondents gave estimates of the overall accuracy of the apparatus they were using which varied from 5 to 30%. It was further pointed out that for most of the work for which the apparatus was used, the required accuracy was not greater than that obtained, since radio field intensity is subject to relatively large variations in space and time under the conditions normally prevailing in radio communication. Brief details of the results of such comparisons of which the information has become available are given below under the headings of the respective countries.

(*b*) *Comparison Tests in Great Britain.* — The British Post Office carried out comparison tests in 1930 between apparatus of the Marconi and Western Electric type, on a wave-length of 24.5 metres and obtained a maximum discrepancy of 25% over the whole range of 5 to 1200 microvolts per metre. In a subsequent test between the Western Electric set and an experimental set developed by the Radio Research Board, on wave-lengths between 35 and 60 metres, agreement was obtained to within 15% for field strengths varying from 70 to 250 μV/m. Later tests carried out in 1931 showed that over the wave-length range of 16 to 34 metres the ratio of the field strength measured on the P. O. Western Electric set to that on the Marconi set varied from 2.2 (+ 7 db.) at the short waves to 0.6 (— 5 db.) at the longer wave-lengths.

In a test carried out at Harwich in 1931, the British Broadcasting Corporation compared their own Western Electric set with one of the Marconi type and with two sets produced by Messrs. Philips of Eindhoven, Holland. Using the emissions from broadcasting stations on wave-lengths between 261 and 473 metres, the three types of sets alwys agreed within 20 %, the difference in the measured field-strengths being generally much less than this amount.

(*c*) *Comparison Tests in United States of America.* — In the United States of America, the Bureau of Standards have carried out investigations with a view to establishing the absolute accuracy of their several equipments for measuring field strengths. These equipments comprise a Western Electric Co. type 44A set with loop aerial, and two other sets for high and low frequencies respectively, employing open antennae. Intercomparison tests have been made using a loop, a vertical aerial and a condenser antenna, and the maximum discrepancy obtained was of the order of 20%, the majority of the results, however, being in agreement to less than 10%, which is claimed as the absolute accuracy of the type 44A set over its frequency range 200 to 6000 kc/s. A somewhat similar accuracy of 12.5% (1 db.) is also suggested by R. C. A. Communications, the General Electric Co. (N. Y.) and the Bell Telephone Laboratories as being obtainable with the respective apparatus employed by these organisations. The B. T. L. apparatus covers, in four sets, the frequency range of 17 to 200,000 kc/s (wavelengths 17,500 to 1.5 m.) and comparisons with it have been made by the Bureau of Standards, R. C. A. Communications, the British Post Office and the Japanese administration.

(*d*) *Comparison Tests in France.* — Tests carried out by Les Laboratoires L. M. T. with their own (i. e. Standard Telephones & Cables) equipment gave agreement within 40% (2 or 3 db.) on long waves with the corresponding apparatus used by the British Post Office, while at broadcasting wave-lengths a comparison with apparatus at the Laboratoire National de Radioélectricité, using a mutual inductance attenuator, showed a difference of 10% in the measured values.

(*e*) *Comparison Tests in Germany.* — The Reichspostzentralamt employ field-strength measuring apparatus developed by G. Leithauser, G. Anders, M. Baumler and, more recently, by M. von Ardenne, for use at frequencies from 15 to 20,000 kc/s. An overall accuracy of 10 to 20% is claimed for the measured values based upon a comparison with other German apparatus and with the equipment produced by Van der Pol of Messrs. Philips, Holland.

(*f*) *Comparison Tests in Canada.* — The Canadian Marconi Company has itself carried out intercomparisons of Marconi equipment type 205, RCA-Victor type TMV-21-A and a composite set incorporating a broadcast receiver and a signal generator. In the broadcasting band of frequencies from 500 to 1500 kc/s., agreement was obtained to within 12%. The Canadian Radio Broadcasting Commission claims to have obtained agreement to 5% between equipments of the R. C. A. and Marconi types.

5. CONCLUSIONS. — In conclusion, it is convenient to summarise very briefly the results of this survey of the methods of measuring radio field intensity in use in various parts of the world. In the first place, it appears to be desirable that, wherever possible, a loop receiving antenna should be employed, this loop being symmetrically arranged and connected so as to be free from spurious errors. The effective height of the loop is calculated from the well-known formula involving its dimensions, number of turns and the wave-length employed. If the use of an open antenna is unavoidable, this should be calibrated by means of a loop and with the aid of a local transmitter.

After obtaining an indication of the incoming signal with the loop and its associated receiver, it is then necessary to calibrate the whole apparatus by injecting into the loop an e. m. f. of such magnitude as to produce the same indication as that of the signal. This e. m. f. is introduced into apparatus in use alternatively by means of a current through a resistance at the centre of the loop, by a mutual inductance or by a capacitive potentiometer arrangement. As far as can be ascertained, the method of obtaining the attenuation for the introduction of this calibrating signal represents the salient difference between the types of apparatus in most general use. In the most widely used commercial apparatus, the adjustment of the indication from the locally generated e. m. f. is controlled by a resistance attenuator operating at the intermediate frequency of the receiving amplifier. In the second type of apparatus referred to above, the attenuation is carried out at the signal frequency with or without the addition of a variable mutual inductance.

The overall accuracy of the apparatus developed for the absolute determination of field intensity is generally claimed by those responsible for it to be better than 12% (1 db.), while for relative measurements it appears that the indications can be relied upon to 5% or less. It mut be remarked, however, that in the relatively small number of comparison tests of both a national and international nature, of which information is available, discrepancies ranging up to over 100% have been observed although, in general, agreement has been obtained to within 20%. The data available are insufficient to permit of any more precise statement on this subject. In discussing whether it is desirable to arrange for any more systematic and detailed comparisons of field strength measuring apparatus to be carried out, the requisite accuracy for the various phases of radio communication should receive consideration.

The following extracts from the replies received are offered as being helpful in deciding the future course of action in this subject.

(1) « It is suggested that the several National Laboratories set up field intensity standards and that steps be taken if possible to make intercomparisons of these. Such comparisons would be particularly valuable if the methods used by the different laboratories differed in essential details. »

J. H. Dellinger,
Bureau of Standards.

(2) « It seems to me that the most difficult problem is to reach an agreement on a standard antenna. At high frequencies, the field intensity varies with height above ground, and in many cases, both the vertical and horizontal components are of interest. We generally use the horizontal component, and the measurement of the greatest interest to us is the horizontal component, measured at the height above the ground generally used of our directive receiving antennas. »

H. H. Beverage,
R. C. A. Communications, Inc.

(3) « It would be of value to obtain data from various sources on the accuracy of effective height calculations based upon field intensity measurements made from 1 to 20 wave-lengths away from the radiator. »

Chief Signal Officer,
War Departmant, U. S. A.

(4) « It is very interesting to know that it will be possible in the near future for organisations who are interested in the matter of field intensities to have an opportunity to compare notes and equipment for establishing methods of measurements. This will tend to eliminate the disputes of misunderstanding which arise from work of this type of service. »

R. B. Parrish,
Pacific Engineering Laboratory Company

(5) « How is the field strength of a fading signal determined ? Is it an average value and if so, over what period of time ? Or is it an average maximum value and how is this average maximum determined ? »

J. F. Byrne,
Ohio State University.

(6) « The dependence of the effective e. m. f. induced in an open aerial on the resistance of the earth connection is at present insufficiently understood.

The comparison of the results obtained with open aerials and with closed loops would appear to merit further investigation. »

National Physical Laboratory.

(7) « The scope of the enquiry might be extended to cover the recording of field strength over a period of time, e. g. records of signals from a distance at night. We use an analysing recorder which indicates at the end of a period the time during which the field strength exceeded any of 10 values which have been pre-determined, i. e. give peak and quasi-maximum for various percentages of total time. »

British Broadcasting Corporation.

(8) « In descriptions of short-wave field strengths it is very desirable that the form of antenna employed should be stated, since this is important for the understanding of the figures quoted. Frames are not suitable for short-waves, since for many measurements no direction of the frame for minimum signal is obtained. »

Reichspostzentralamt.

(See end p. 180).

APPENDIX I

Summary of Replies to Questionnaire on Methods fo Measuring Radio Field Intensity

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity μV/*n*			
United States of America Bureau of Standards. (J. H. Dellinger)	(*a*) L	34 (W.E. type 44A)	200-6000	20-7 × 10^6	Attenuation at 83 kc/s.	10	Comparison between measured and calculated values.
	(*b*) A	61	540-20,000	0.1-10,000		10	—
	(*c*) A	9	10-30	10-6,000		5	Comparison with A. T. & T. and R. C. A. apparatus gave agreement to ±15%.
Bell Telephone Laboratories (C. R. Englund)	(*a*) L	20, 30, 31, 32, 34, 42, 43, 56, 68.	17-65	10-20,000	Resistance attenuator at low or intermediate frequencies.	5	Compared with R. C. A. Commns., Bureau of Standards, British P. O., Japanese Administration. Also numerous cross checks made with different aerials and loops.
	(*b*) L		550-2000	10-50,000			
	(*c*) L & A		2.5-19 (mc/s)	0.2-2,000			
	(*d*) A		60-200 (mc/s)	2-500			
Federal Radio Commission. (C. B. Jolliffe)	L	34 (W.E. type 44A)	200-6000	10-7 × 10^6	Resistance attenuator at intermediate frequency.	5	Accuracy verified at Bureau of Standards.
National Association of of Broadcasters. (J. C. McNary)	(*a*) L	34 (W. E. type 44A)	200-6000	20-700,000	Resistance attenuator at 83 kc/s.	10	
	(*b*) L	RCA Victor Co. TMV21	550-4500	20-3 × 10^6	—	20	
	(*c*) L	—	550-6000	100-2.5 × 10^6	Calibrating oscillator	10	
Tufts College. (G. W. Kenrick)	(*a*) L & A combination	49	16-18	10-5000	G. R. Standard Signal Generator	15-20	A few comparison tests with other observers.
	(*b*) A	50	770	10-2000		15-20	
	(*c*) A	50	6000	10-2000		50	

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity $\mu V/n$			
U. S. A. (*Contd.*) Naval Research Laboratory. (A. H. Taylor)	(*a*) L (*b*) L	34	200-5800 750-18.500	30-800,000 $5\text{-}10^6$	Attenuator at 83 kc/s. Attenuator at 258 kc/s.	20	— —
War Department. (R. B. Colton)	L	34 (W.E. type 44A)	200-6000			5	—
R. C. A. Communications Inc. (H. H. Beverage)	L & A	18	15-30,000	—	Attenuator calibrated against non-inductive condenser or concentric tube inductance.	5	Comparisons made between loop & condenser antennae.
	A	Unpublished pamphlet	-450,000	—		10	
General Electric Co. (E. F. W. Alexanderson)	L & A	11	100-30,000	$10\text{-}2 \times 10^6$	Calibrating oscillator.	10	Comparisons made with other laboratories & by different methods.
Pacific Engineering Laboratory Company. (R. B. Parrish)	L	34	200-15,000	4-?	Attenuation at intermediate frequency.	20	Checks made with other apparatus of same type.
Ohio State University. (J. F. Byrne)	L	34	500-5,000	$1\text{-}10^6$	Resistance attenuator at 55 kc/s.	10	Compared with W.E. type 44A. Also compared with G. R. Signal Generator.
Jansky & Bailey. (C. M. Jansky, Jr.)	L	—	550-1,500	—	Calibrating oscillator.	5	Compared with B. T. L. & R. C. A. sets.
Great Britain. National Physical Laboratory. (Radio Department)	L & A	36, 37, 38, 58.	10-15,000	$1\text{-}10^6$	Calibrating oscillator & attenuator at signal frequency.	10-25	Compared with P. O. set.
General Post Office (Radio Section)	L or A	20, 34	10-30,000	$0.5\text{-}10^6$	Attenuation at intermediate frequency.	6 (0.5 db.)	Compared with N. P. L, B. B. C., Marconi Co., A. T. & T. C^o.

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity $\mu V/n$			
Great Britain (Contd.) British Broadcasting Corporation (N. Ashbridge)	L	84, 70, 81. Also unpublished report	150-21,000	—	Attenuation at signal & intermediate frequencies.	5-10	Comparison tests with Marconi Co., N. P. L., & Philips (Eindhoven)
Cavendish Laboratory, Cambridge. (J. A. Ratcliffe)	L or A	65, 80	200-1,500	$2\text{-}3 \times 10^6$	Capacitance potential divider at signal frequency.	5	Agreement between measured & calculated field intensities obtained to about 5%
Standard Telephones & Cables Ltd.	(*a*) L (*b*) L (*c*) A	34, 78.	15-80 150-1500 3-30(mc/s.)	$0.5\text{-}5 \times 10^5$ $100\text{-}8 \times 10^6$ $1\text{-}10^5$		10 10 50 (4 db)	— — Comparison made with P. O. Agreement to 6% (0.5 db).
Germany Reichspostzentralamt. (H. Harbich)	L & A	2, 3, 6, 13, 15, 48	15-20,000	$1\text{-}2 \times 10^6$	Variable mutual inductance or capacitance potential divider.	10-20	Compared with Philips set.
Heinrich Hertz Institute (H. E. Hollmann)	L	34 with modifications.	100-1000	1-100	Attenuation at intermediate frequency by dynamic resistance of a valve.	20	—
Telefunken Company.	L	17	15-37.5 150-1500	$2\text{-}2 \times 10^6$	Variable mutual inductance at signal frequency	—	—
M. von Ardenne	L	6, 7	100-1000	—	Capacitance potential divider.	10	Compared with Reichspostzentralamt.
Deutsche Versuchsanstalt für Luftfahrt. (H. Fassbender)	L & A	1, 2, 29, 41	100-3000	1-?	Variable mutual inductance at signal frequency.	10	—

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity $\mu V/n$			
Japan Ministry of Communications (Electrotechnical Laboratory).	(*a*) A (*b*) L & A (*c*) L & A	34, 59, 60	13-40 40-3000 3-30(mc/s.)	1-?	Resistance attenuation at signal & intermediate frequencies.	5	Compared with W. E. apparatus; agreement to 10% (1 or 2 db.).
Military Scientific Laboratory.		28 (Marconi type 205)	600-23,000	—	Resistance attenuator & variable mutual inductance at signal frequency.	—	—
Naval Experimental & Research Establishment.	A	—	15-30 100-300 10-15 (mc/s.)	— — —	Variable mutual inductance.	—	—
Broadcasting Corporation of Japan	(*a*) L (*b*) L	—	150-1500 150-3000	100-2 × 10^6 10-2 × 10^6	Resistance attenuator at signal frequency.	—	—
Canada Department of Marine, Radio branch. (C. P. Edwards)	L	42	550-1300	50-1.5 × 10^5	Resistance attenuator at signal frequency.	10	Compared with other apparatus of similar type.
Radio Broadcasting Commission	L	Unpublished bulletin	500-1500	20-3 × 10^6	Either variable mutual inductance or resistance attenuator at signal frequency.	5	Compared with Canadian Marconi Standard Set.
Canadian Marconi Co. (J. H. Thompson)	(*a*) L (*b*) L	28 (Marconi Type 205) RCA Victor, Type TMV-21-A	500-18,750	3-3 × 10^6	Resistance attenuator & variable mutual inductance at signal frequency.	12	Intercomparison of different types of equipment made.
France Laboratoire National de Radioélectricité. (P. David)	L or A	24, 25, 26, 51.	15-20,000	1-10^6	Variable mutual inductance at signal frequency.	5	Comparison made between measured & calculated values of field intensity.

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity $\mu V/n$			
France (*suite*) Les Laboratoires L. M. T. (E. M. Deloraine)	(*a*) L (*b*) L (*c*) A	20, 30, 31, 34	15-80 150-1500 3-30 (mc/s.)	0.5-50,000 $100\text{-}8 \times 10^5$ $1\text{-}10^5$	Resistance attenuation at intermediate frequency.	12 (1 db.)	Agreement with British P. O. to 25% (2 or 3 db.). Also compared with L. N. R & difference of 10% obtained.
Société Française Radioélectrique.	L	24, 25, 26 L. N. R. method	85-3000	200-?	Variable mutual inductance at signal frequency.	5	—
Holland Dutch State Telegraphs. (Chief of Radio Laboratory)	L	—	15-1500	$0.1\text{-}2 \times 10^4$	Resistance attenuator & variable mutual inductance at signal frequency.	20-30	—
Philips Radio Laboratory. (B. van der Pol)	L	Unpublished document	150-1500	$50\text{-}2.5 \times 10^6$	Resistance attenuator at signal frequency.	5	Compared with British Marconi & B. B. C. sets, also with Reichspostzentralamt set. Agreement to 10%.
Czekoslovakia. Ministry of Posts and Telegraphs	L	34 Western Electric type 44A.	150-1500	$100\text{-}2 \times 10^4$	Resistance attenuator at signal or intermediate frequency.	5	—
Denmark. Direction générale des Postes et des Télégraphes (K. Christiansen)	(*a*) L	34 (W.E. type 44A)	150-1500	$100\text{-}5 \times 10^5$	Resistance attenuator at signal or intermediate frequency.	10	—
	(*b*) L	Philips Laby. set.			Resistance attenuator at signal frequency.	10	—

Name or Institution	Type of antenna A = open aerial L = closed loop	Reference to Description of Set. (See Appendix II)	Range		Method of Voltage Calibration	Estimated Overall Accuracy (per cent)	Comparison Tests
			Frequency kc/s.	Intensity $\mu V/n$			
Poland Radiotechnical Institute. (J. Groskowski)	(*a*) L & A	18 (RCA)	15-100	30-250	Variable mutual inductance at signal frequency.	5	Comparison tests with Japanese Ministry of Communications.
	(*b*) L & A	28 (Marconi)	60-5000	1-100	Resistance attenuator at signal frequency.	10-30	
	(*c*) L & A	Polish Society of Electrical Engineers. Jan. 1932	60-5000	10^4-10^6	Resistance attenuator at signal frequency.	10-30	
	(*d*) L & A		150-1500	200-10^6	Resistance attenuator at signal frequency.	10-30	
Italy Ente Italiano Audizioni Radiofoniche.	L	62	150-1500	100-5 × 10^4	Resistance attenuator at signal frequency.	15	—
Ministère de la Guerre	A	—	—	—	Direct measurement of resistance of & current in antenna	2-3	—

(9) « Most of the important points regarding the measurement of field intensity are well pointed out in your information. It will become more complete if you add some remarks with regard to the measurement of short-wave signals and external noises. »

Ministry of Communications, Japan.

(10) « (*a*) To what time space are to be referred the measured mean values of the field strength and in what amount are to be taken into account the fluctuations of the latter ?

(*b*) How are field strength measurements in large cities to be carried out ? Are they to be taken on the surface of the streets, on the roofs of the buildings or on places as far as possible clear ? »

J. Groszkowski, Warsaw.

APPENDIX II

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75. *K. Sreenivasan.* — Survey of Some Methods of Radio Signal Measurement. Wireless Eng., 1928, vol. 5, 205.
76. *P. B. Taylor.* — A Compact Radio Field Strength Meter. Proc. Inst. Rad. Eng., 1934, vol. 22, 191.
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80. *L. G. Vedy* and *A. F. Wilkins.* — A portable Apparatus for Measuring the Magnetic Field Strength in an E. M. Wave. Proc. Camb. Phil. Soc., 131, vol. 27, 481.
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Nº 51. — **The measurement of frequency,** by L. Essen, B. Sc., National Physical Laboratory.

The accuracy of a frequency determination usually depends on :

(*a*) The accuracy with which the standard frequency is known,

(*b*) The accuracy of the measurements in terms of the standard.

The frequency of the standard can be obtained by reference to the present astronomical time signals with an accuracy depending on the stability of the standard. If the stability is such that the measurements can be averaged over monthly periods then an accuracy of 0.1 part in 10^7 can be realised.

When the frequency bears a simple harmonic relationship to the standard, then beats may be obtained directly between appropriate harmonics and an accuracy of measurement better than 1 part in 10^7 is readily attained. In general, however, it is necessary to interpolate between two known frequencies derived from the standard by some such means as an auxiliary oscillator. The errors introduced by interpolation usually amount to more than 10 parts in 10^7.

These errors due to interpolation have been eliminated at the National Physical Laboratory for frequencies up to 1.200 kc/s and it is hoped to make the method applicable for the measurement of higher frequencies.

The frequency of the standard used at the Laboratory is 20 kc/s and this standard is used to control multivibrators at 1 kc/s., 20 kc/s and 80 kc/s. By the use of these multivibrators it is always possible to obtain a beat note of between 500 and 1,000 cycles per second between a known standard frequency and the frequency being measured. This beat note is measured by direct comparison with a series of standard audio frequencies derived by demultiplication of the 80 kc/s note.

The unknown frequency is thus referred directly to the standard oscillator of 20 kc/s, and may be measured with an accuracy greater than 1 part in 10^7.

Nº 52. — **La précision des horloges à quartz dans les services horaires,** par N. STOYKO, Bureau International de l'Heure, Paris.

La variation accidentelle journalière de la pendule moyenne (δ) des trois services horaires (Greenwich, Leningrad, Paris), est presque la même (0,001 sec.) pour 1931, bien que ces trois observatoires utilisent des pendules de systèmes différents : Shortt, Riefler et Leroy respectivement. Il en résulte que pour augmenter la précision de l'heure, il faut trouver un garde-temps nouveau.

Depuis le 1^er^ septembre 1933, l'Observatoire Naval de Hambourg utilise une horloge à quartz. Pour comparer les résultats obtenus avant et après la mise en service de cette horloge, nous avons divisé l'année 1933 en deux parties : A) avant et B) après le 1^er^ septembre. En utilisant les formules employées pour l'étude de 1931, nous avons trouvé en secondes :

	c	δ	μ
A	0,002.99	0,003.26	0,015.16
B	0,002.70	0,000.40	0,003.20

où c est l'erreur accidentelle de calcul et μ l'erreur résiduelle due à la détermination astronomique de l'heure.

On remarque que c est resté presque le même tandis que μ et δ, qui dépendent essentiellement de la qualité du garde-temps, ont considérablement diminué. Cela montre que le remplacement à Hambourg des pendules Riefler par des horloges à quartz a marqué un progrès réel.

A titre de comparaison, nous avons effectué le même calcul pour Greenwich (Pendules Shortt) :

	c	δ	μ
A	0,002.50	0,000.64	0,004.28
B	0,002.77	0,000.65	0,003.86

Pour Greenwich, la précision du service n'a donc pas changé.

Nº 53. — **An analysis of continuous records of field intensity at broadcast frequencies,** by S. S. KIRBY, K. A. NORTON, and G. H. LEBSTER, National Bureau of Standards.

Continuous records of the field intensities of most of the broadcasting stations in the United States were made at the National Bureau of Standards receiving station near Washington, D. C. Typical records of received field intensities from a number of stations are presented. Maximum field intensities during ten-minute time intervals were analyzed in the following ways to illustrate sky-wave propagation phenomena at broadcast frequencies, for distances up to 4000 kilometres : (1) The diurnal variation of the ten-minute maxima (equivalent to quasi-maximum values) is given for several stations. (2*a*) The variation of the ten-minute maxima is shown with respect to distance for night field intensities. (2*b*) These variations are also shown for sky waves received during the daytime. Empirical formulas are developed to represent the data of (2*a*) and (2*b*). The data are explained in terms of a theory of propagation of waves in the ionosphere.

The following deductions were made from an analysis of the data : Received night field intensities are often greater than inverse distance, reaching their maximum values at about 600 kilometres. There are no large variations of received field intensity at night with season or frequency, although, in general, the received field intensity is slightly weaker in summer. The variation of the received field intensity at night with distance is determined primarily by the directional characteristics in the vertical plane of the transmitting and receiving antennas. The results obtained are most easily explained on the assumption of a refracting rather than a reflecting layer in the ionosphere. The received field intensities during the daytime at distances greater than about 600 kilometres are sky waves. (¹).

(¹) To be publisched in the Bureau of Standards Journ. of Research.

N° 54. — **Frequency distribution of intensities of radio atmospherics,** by K. A. Norton.

The variation of intensity of radio atmospherics with frequency is determined by two factors, (*a*) the production of atmospherics, and(*b*) the propagation of the atmospherics to the receiver. A general formula for the propagation factor is derived. The Eckersley-Van der Pol attenuation formulas for the ground wave are presentend in a simplified graphical form. These formulas are then used in the general formula to determine the propagation factor under conditions such that most of the atmospherics arrive as ground waves. In conjunction with the empirical Austin-Cohen formula, the method is used to calculate the frequency distribution of atmospherics in the frequency band from 10 to 60 kc. over sea water. The agreement between theory and measurement data is satisfactory (¹).

N° 55. — **Report of the British National Committee to Commission III on investigations on atmospherics carried out in Great Britain from April 1931 to June 1934,** by R. A. Watson-Watt, National Physical Laboratory. — (Full text).

This report on atmospherics research in Great Britain since 1931 is divided, for convenience, into three parts. The first concerns resolutions passed by the General Assembly at Copenhagen, the second enumerates the books and papers, bearing on atmospherics research, published in Great Britain since 1931, and the third outlines briefly the state of researches not adequately covered by publication. This last section is made brief because two of its principal subjects are otherwise provided for in the Agenda of Commission III.

I. — COPENHAGEN RESOLUTIONS

The following matters, involving participation by the British National Committee or by its delegate to Commission III of the Union Radio Scientifique Internationale, arise from the proceedings at Copenhagen.

Design and Distribution of Apparatus. — The sub-committee, consisting of Messrs. Austin Snyder, and Watson Watt, appointed at Copenhagen to continue the work of the Snyder-Watson Watt committee appointed at Brussels, has made no progress. The much regretted death of one of its members, and the general economic situation have contributed to this lack of progress. Reconsideration at the London meeting will be required.

Standing Sub-commission of Commission III. — No meetings and no correspondence have occurred since the Copenhagen conference.

List of Recording Stations. — No additions have been made to the list of stations in Great Britain included in the preliminary list prepared at Copenhagen. A fuller statement can be supplied at London if required.

Specification of methods used. — The methods used in the more important sections of atmospherics research in Great Britain have been very fully detailed in a monograph on « Applications of the Cathode-Ray Oscillograph in Radio Research » referred to below. No other specifications have, in the absence of indications that they would be immediately useful, been prepared. No specifications from other countries have been submitted for scrutiny.

Preferred Frequencies. — The cathode-ray direction-finder has been operated on the frequency band 10 ± 0.15 kc/sec. since July 1930; the narrow-sector pen-recorder on 10±1 kc/sec. The increasing difficulty of finding frequency bands not fully occupied by signals may cause some changes in preferences for atmospherics work.

Exchange of Data. — Data from the fixed-band intensity recorder were supplied to Paris and Warsaw for the periods April 1929 to March 1932. Data were received in exchange from Paris for the period April 1929 to July 1932, from Warsaw December 1931 to June 1934

(¹) To be published in the Bureau of Standards Journal of Research.

and fom Zi-Ka-Wei January 1932 to December 1933. The cessation of recording at Slough by this method interrupted the exchange.

Polar Year Work. —It was not found practical to include work on atmospherics in the programme of the British Polar Year party at Tromoe. The work normally in progress at Slough and Leuchars was regarded as the maximum that could be undertaken in the Polar Year, having regard to the extensive provision required for ionospheric research.

Radiocinemographe. — The radiocinemographe which it was recommended should be handed over by the French National Committee to the British has not been received. It has therefore been impossible to operate and measure the characteristics of the apparatus as requested.

Cathode-Ray Direction-Finding. — No information has been received as to the ability of the Polish, French, American and Danish Committees to participate in simultaneous or quasi-simultaneous observations on the direction of arrival of individual atmospherics. Work has been carried out in Australia and in Canada, but no quasi-simultaneous programmes have yet been arranged.

International Co-operation on measurement of lightning fields and atmospherics. —No U. R. S. I. action appears to have been taken on the resolutions dealing with this subject, and no British action has therefore arisen.

Supply of Data on Locations of Sources of Atmospherics. — In accordance with the resolution submitted by Commission IV at Copenhagen, the Radio Research Board acceded to the request of the British Committee for transmission to Paris of data on locations of predominant sources of atmospherics, to be included in ursigrams. Data was sent to Paris by Air Mail each week from 4th July 1931 until the end of the trial period of twelve months for which the Radio Research Board had untertaken to supply data. This matter is fully dealt with in a report to the Chairman of the British National Committee, which is included as an Appendix to this report; this inclusion is made in order that Commissions III and IV may have before them material neccessary for re-consideration of the matter.

II. — PUBLICATIONS

The publications bearing on atmospherics research may be divided into three classes, dealing respectively with (*a*) investigations on lightning and the electricity of thunderstorms, (*b*) instrumental technique of atmospherics research, (*c*) observational results of atmospherics research.

Class (*a*) has, in Great Britain since 1931, included the following communications, viz:

The Present Position of Theories of the Electricity of Thunderstorms. Watson Watt. Quaterly Journal Royal Meteorological Society 57, p. 133, 1931.

The Polarity of Thunderclouds. Halliday. Proceedings Royal Society A, 138, p. 205, 1932.

On the Electric Charge collected by Water Drops. Gotz. Proceedings Royal Society A, 142, p. 248, 1933.

The Propagation of a Lightning Discharge through the Atmosphere. Halliday. Philosophical Magazine, 15, 409, 1933.

Branching of Lightning. Macnair. Nature, 128, 969, 1931.

Branching of Lightning. Schonland and Allibone. Nature, 128, 794, 1931.

Progressive Lightning. Schonland. Proceedings of the Royal Society, 112, 69, 1933.

Sources of Atmospherics and Penetrating Radiation. Appleton and Bowen. Nature, 132, 965, 1933.

Thunderstorms and the Penetrating Radiation. Halliday. Proceedings of the Cambridge Philosophical Society, 30 II, 206, 1934.

Class (*b*) has included :

(1) Report of the Radio Research Board for the period ending 31st December 1930.

Report of the Radio Research Board for the year 1931.

Report of the Radio Research Board for the period 1st January 1932 to 30th September 1933.

(2) Cathode Ray Oscillography. Watson Watt. Journal of Scientific Instruments. February 1933.

(3) Applications of the Cathode-Ray Oscillograh in Radio Research. Watson Watt. Herd and Bainbridge-Bell. H. M. S. O., 1933.

(4) Cathode Ray Photography of Random Electrical Transcients. F. W. Chapman. Nature, 131, p. 620, 1933.

Class (*c*) has included, in addition to the reports of the Radio Research Board cited above :

La Météorologie et la Radiogoniométrie des Atmosphériques. Watson Watt. La Météorologie, N^{os} 73-75, April-June 1931.

Les Atmosphériques et l'Eclair. Watson Watt. La Météorologie, N^{os} 73-75, April-June 1931.

The Meteorological Relations of Atmospherics. Watson Watt and Bureau. Quaterly Journal of the Royal Meteorological Society, 57, 221, 1931.

III. — STATE OF WORK

Directional Recording. — The narrow-sector pen-writing recorder has been maintained in operation at Slough throughout the period under review. It operates in the frequency band 10 ± 1 kc/sec, and has been worked as an unbiguous recorder throughout the whole period The records of this instrument, operating on a simple cardioid diagram since June 1933, have been utilised in the provision of a « thunderstorm index » figure for use in ionospheric studies.

Cathode-Ray Direction-Finding. — The photographic methods referred to in the corresponding report for the Copenhagen meeting have been further developed in the interval and have completely replaced the visual method. The technique is described in considerable detail in the monograph on « Applications of the Cathode-Ray Oscillograph in Radio Research » mentioned in Section II of this report. Since the apparatus, with still more recent modifications, will be demonstrated to members who are able to visit Radio Reserach Station, and in view of the proposed discussion on « Location of Sources by cathode-ray direction-finding », it is not thought necessary to deal more fully with the technique in this report.

It may, however, be said, in relation to observational results, that the development in technique has been so sustained that it has not been thought desirable to divert attention from it to the detailed comparison of the results with meteorological data. The stage now reached is such that the incidents of propagation are of predominant importance in limiting the accuracy of location; in particular the abnormal polarisation of the received atmospheric has made it desirable to attempt the introduction of a long-wave spaced-aerial (« Adcock ») direction-finder for the work. The very considerable technical difficulties of producing such an apparatus are now being surmounted in experimental development work. It may be desirable to emphasise that these propagational troubles assume importance in this application mainly because of the present limitation of the observing network to two stations only 500 km. apart. The addition of a third station, preferably at a greater distance, would reduce the stringency of the demands for azimuthal accuracy at each station, although this accuracy should, of course, be made as high as is technically and economically convenient.

Wave-Form of Atmospherics. — The development of photographic methods in application to this side of the investigations had just begun at the time of last report. The von Ardenne oscillograph and the more recently developed Cossor oscillograph have permitted great advances in the method; some of these are outlined in the monograph already mentioned. Important improvements have, however, been effected since the publication of the monograph, and will be outlined in the course of the London meeting. In particular the paper by Appleton and Watson Watt will deal with the present position sufficiently fully to obviate the need of further report here on the work at Radio Resarch Station and at King's College, London.

Energy Spectrum of Atmospherics. — In the absence of progress recorded at the beginning of Part I of this report, the general investigation of this problem at Radio Research Station remains in abeyance. The single-element fixed-band recorder was operated on 85 kc/sec. ± 10 c/sec. from the date of last report to 6th December 1932, and was then put out of action, pending re-examination of the demand for data of this character, and to avoid interference with other items of investigation.

Synchronous Observation by Picture Recording. — This method of recording was continued until 25th June, 1932, when it was concluded that the data obtained were sufficiently representative, and that if confirmed, on a wider scale but in less detail, the evidence obtained by simultaneous photography of wave-form and direction of arrival at two stations.

Synchronous Observation by Photography. — The technique of photographic recording developed for the cathode-ray direction-finder and for the registration of wave-form of atmospherics has been applied in several series of synchronous observations, in which records of both kinds have been made at Slough and Leuchars, using a common time-marking system conveyed by land-line.

APPENDIX

Report on Supply of Atmospherics Data for Ursigrams

426/S/HB. 19th April, 1934.

Professor E. V. Appleton, M. A., D. Sc., F. R. S.,
Halley Stewart Laboratory,
30, Chesterford Gardens,
Hampstead, N. W. 3.

My dear Appleton,

In accordance with the request of the British National Committee, I give you hereunder an outline of the history of communication of atmospheric data to be radiated in the French Ursigram.

On the request of the U. R. S. I., the British Committee asked the Radio Research Board to communicate to Paris, for inclusion in Ursigrams, data on the predominant sources of atmospherics located by cathode-ray direction-finding on the 500 km. base-line Slough-Leuchars. The Radio Board recommended that a weekly tabulation of daily observations be sent to Paris by air mail on Saturdays, to be radiated in the Monday Ursigrams. It recommended also that the arrangement should operate for a trial period of twelve months, with review on the evidence of use or usefulness thus provided. The French National Committee asked that the data be sent to the Office National Météorologique, which would undertake its inclusion in Ursigrams. Data was sent weekly from 4th July, 1931.

On 11th September 1931, Général Delcambre, Director of the O. N. M., wrote to me as follows: « I receive very regularly the weekly tables in which you give the locations of the principal sources of atmospherics. On the very day of receipt (i. e. in general on Mondays) this data is added to the Ursigram emitted by Bordeaux. Up to 1st September this transmission was in plain language. But the impossibility of continuing to send such long messages has led me to adopt a provisional code which has been communicated to « Science Service » and of which you will find a copy enclosed (Appendix I). I propose to modify this code to take account of the additional information which you are sending me since 1st September (see this amended code in Appendix II) (Appendices not reproduced here).

The comparison of the date which you send with the meteorological charts is very instructive, and one foresees the time when meteorologists will no longer wish to draw charts without having locations of sources of atmospherics at their disposal.

The present experiment shows the usefulness of your messages and I hope it will hasten the moment when they can be sent by radio and not by mail. »

On 6th August 1932, I notified Général Delcambre of the suspension of reporting on the termination of a trial period somewhat exceeding the twelve months proposed, and asking for his remarks on the general situation. Commandant Bureau, signing for Général Delcambre, replied as follows :

« I am in receipt of your letter of 6th August and hasten to give you my opinion on the subject of 12 months of Ursigrams.

1. *Meteorological Comparisons.* — The data on sources of atmospherics has been compared with the meteorological charts for 1300 G. M. T., not with a view to weather forecasting but to take account of the probable relations between sources of atmospherics and the position of fronts especially in the charts for the Northern hemisphere. It must be recognised that this comparison is very encouraging. The phenomena are far from having always the great simplicity which certain theories would have suggested, but numerous examples have a very great interest, if only from the point of view of the meteorologist.

To pass from the state of retrospective studies to the state of daily utilisation in the more complete analysis of meteorological charts, it is evidently desirable that :

(*a*) the data should be sent daily, if possible by radio,

(*b*) that it should be sent without gaps, i. e. even on Saturdays, Sundays and holidays.

The great difficulty of attaining this does not escape me. I am also conscious of the very great labour already represented by the observations made in the course of the last twelve months.

2. *Radioelectric Comparisons.* — The Ursigrams have also been utilised in France from a more purely radio-electrical point of view; the comparison between this data and that given by the French recorders, in relation to the level of atmospherics at 1300 G. M. T. and to their direction at that moment. On the whole the agreement is satisfactory and this weekly despatch has certainly contributed to bring us still nearer to the very desirable goal of a rigorous comparability of the results obtained in different countries.

This comparison bears also on the effect of diurnal variation and the choice of the hour of observation. This choice is, in fact, of capital importance. That of the present hour, 1300 G. M. T. seems to have been guided by the desire for simultaneity with one of the world networks of meteorological observations, the 1300 G. M. T. network being without any doubt the most important. There does not seem to be at the moment any need for proposing a change of hour. But it would always be an advantage to have available recorders of mean level of atmospherics and of their direction in order to be able to utilise correctly the very precise results of goniometric determinations at fixed hours.

3. *Diffusion of ursigrams.* — Immediately on receipt of the weekly letter, the results obtained by the British Committee were diffused by radio (from Bordeaux) by the French Committee so that they should reach correspondents in Europe and America. To facilitate the transmissions, a very simple code has been used. I have received no comments on it; this does not mean that it requires no improvement. I know that the Ursigrams are followed with interest in the U. S. A., in Poland, and, by a certain number of amateurs, in France and in Great Britain. But I have no information on the use that may have been made of the part of the message dealing with atmospherics.

A question which suggests itself is that of the precision of the data sent. I think it would be dangerous to try to send too detailed data. For a first daily trial, such as we could at present undertake, the data should be in very simple form. That adopted by the British Committee, which contents itself with indicating two sorts of sources, concentrated sources and extended sources, seems to me completely satisfactory. If for certain studies it seemed necessary to have certain days of very detailed data, the persons desiring this whould always be free to write to the British Committee. But it is clear that in the present state of the researches, no one would have the time to analyse in detail, every day, the whole of the data.

To sum up, I think that inquiries on the subject of this emission might comprise, among others, the following questions :

(*a*) Should the present hour of observation be retained. If not, what hours are proposed.

(*b*) Do the data as supplied seem to you capable of rendering service in the construction of meteorological charts.

(*c*) If so do you desire a daily transmission.

(*d*) Is the present code satisfactory. »

This concluding paragraph of the letter referred to my proposal to ask possible users for reports on the use they had in fact made of the twelve months trial emissions. Informal inquiries and indirect evidence all pointed, however, to the fact that the data had not been received in America and that no use had been made of it outside France. In these circumstances no formal inquiry was circulated.

The question has been re-opened in a letter from Dr. Dellinger, in which he says :

«Am I correct in concluding that there was a serious slip of some kind in the effort to get your data on atmospherics into the French Ursigrams ? Your data were not included in the French Ursigrams as received here by radio. Furthermore, at the U. R. S. I. Executive Committee meeting in Paris on October 10, Dr. Jouaust (in charge of the French Ursigrams) said in Dr. Appelton's presence that he had received nothing from the British Committee. Were your data buried in the French Meteorological Office, or did something else happen ? »

I am sending him a copy of this statement in answer to his inquiry. I shall be happy to supply any further information which the British Committee may require on the method of communication of the twelve-months data to Paris.

Yours very sincerely,
(Sgd.) R. A. Watson Watt.

N° 56. — **Ionization changes during a solar eclipse,** by E. V. Appelton and S. Chapman.

The report summarises the results of the radio observations made on the occasion of the eclipses of August 31st 1932 and August 21st 1933.

It may be regarded as established that the normal ionizing agency for regions E and F_1 has a speed closely agreeing with that of light : hence it is natural to identify this agency with ultra-violet light (though observations of the kind here considered cannot rule out the possibility that the agency, for one or more of these layers, consists of very high-speed corpuscles). Similarly there is fairly definite evidence that ultra-violet light contributes at least a part of the normal region F_2 ionization, and a suggestion that corpuscles may also contribute. In future eclipses it is very desirable that attention should be specillay concentrated on this region F_2.

N° 57. — **Rapport sur les recherches relatives à la propagation des ondes radioélectriques courtes entreprises pendant l'Année Polaire,** par R. Jouaust, R. Bureau et J. Habert.

Les auteurs rappellent le programme établi par la Sous-Commission de l'Année Polaire et exposent dans quelles limites il a été exécuté.

Après avoir étudié les résultats et, en particulier, la variation diurne, les influences géophysiques et astrophysiques, la période de 27 jours, les variations annuelles, l'influence de la latitude, les auteurs signalent que l'étude de la propagation est liée au problème des relations encore mystérieuses entre la troposphère et l'ionosphère et concluent de la manière suivante :

« Dans ce rapide aperçu des résultats, encore incomplètement connus et sommairement interprétés, des expériences de propagation des ondes radioélectriques courtes pendant l'Année Polaire, il apparaît que l'action du soleil sur l'ionosphère est prépondérante et peut, dès maintenant, être schématisée.

» Les mauvaises conditions de propagation

dans les régions polaires sont peut-être réalisées par excès d'ionisation dans la couche E (à cause de l'activité aurorale) et par défaut d'ionisation dans la couche F (à cause de la faible incidence des rayons lumineux et de l'absorption de l'ultra-violet).

Il ne faut pas perdre de vue que l'Année Polaire s'est placée à une mauvaise époque, dans le cycle de 11 ans des taches solaires: au voisinage d'un minimum d'activité. Il faut souhaiter que des expériences analogues à celles de l'Année Polaire soient reprises en 1936-37, avec un matériel perfectionné, et des méthodes améliorées dans le sens de la continuité.

Il serait bon de choisir sur la Terre quelques arcs de grands cercles remarquables — arcs de méridiens géographiques, de méridiens magnétiques, arc d'équateur, arc entièrement compris dans une des calottes polaires — et d'étudier systématiquement la propagation le long de ces arcs. L'émetteur pourrait être avantageusement un navire stationné au point choisi. L'émission devrait être continue. La réception devrait utiliser des appareils enregistreurs : c'est l'enregistrement continu qui donne tant de prix à la réception des parasites atmosphériques.

De telles expériences de propagation, jointes à des mesures continues des altitudes de couches ionisées, et à l'enregistrement des parasites atmosphériques,fourniraient des données essentielles, utilisables non seulement en radioélectricité, mais en géophysique et, sans doute aussi en météorologie.

N° 58. — **Rapport sur les recherches relatives aux atmosphériques entreprises pendant l'Année Polaire,** par R. Bureau, R. Failletaz et J. Habert.

Les lignes qui suivent résument le rapport établi pour l'Assemblée Générale sur les recherches relatives aux atmosphériques, entreprises pendant l'Année Polaire, conformément au programme établi par l'U. R. S. I.

Il donne la liste de ces recherches, qui comportent principalement :

a) Des enregistrements du nombre d'atmosphériques, assurés par la France à Paris, Tunis, Rabat, Tamanrasset (Sahara), Scoresby-Sund (Groenland), Zi-Ka-Wei (Chine) et par la Pologne à Varsovie, Tromsoë, l'Ile-des-Ours ;

b) Des enregistrements goniométriques à Paris.

Le matériel employé se composait de fréquencemètres (radiocinémographes) et de goniomètre à secteur étroit et à enregistrement photographique (lampe à néon).

Les résultats ont mis en évidence l'importance de la variation diurne et de ses modifications en fonction de la latitude, les variations annuelles, les ressemblances frappantes et fréquentes entre les courbes de localités très éloignées, les différences systématiques provenant de l'emplacement géographique des stations.

Les enregistrements goniométriques ont montré comment évoluent, au cours de l'année, les directions des principaux flux d'atmosphériques et leur répartition régulière avec les heures de la journée.

Des résultats si cohérents appellent une explication simple. On peut en donner une, basée sur la double intervention de la troposphère quant à la distribution des foyers d'atmosphériques et à l'ionosphère, quant à la propagation à grande distance des ondes qu'ils rayonnent. Elle conduit elle-même à une répartition des principales sources mondiales d'atmosphériques.

Les relations des atmosphériques avec les phénomènes météorologiques, l'ionosphère, les phénomènes géophysiques, sont ensuite étudiées avec détails.

Les rapporteurs concluent en demandant que les enregistrements ne soient pas interrompus, mais rendus permanents et développés le plus possible.

N° 59. — **Sur la comparaison de quelques courbes de la variation diurne des atmosphériques,** par R. Failletaz.

Pour les ondes de 12 et 27 kc/s et pour la station établie par la mission française de l'Année Polaire à Tamanrasset (Hoggar), on a tracé les courbes donnant les valeurs moyennes mensuelles des maxima nocturnes et diurnes. Ces valeurs sont sensiblement égales pour l'onde de 27 kc/s, mais les maxima diurnes sur 12 kc/s sont régulièrement plus élevés que les maxima nocturnes. Cette particularité met en évidence la prépondérance des sources d'autant plus lointaines que la fréquence de l'onde d'enregistrement est basse ; elle montre en même temps que sur 12 kc/s les phénomènes de propagation sont peu manifestes puisque le régime nocturne n'est pas favorisé par rapport au régime diurne. Enfin, l'irrégularité de la courbe annuelle des maxima sur 12 kc/s confirme l'hypothèse de la prépondérance des sources lointaines si l'on admet que cette irrégularité peut provenir de ce que l'enregistreur est influencé par des sources réparties sur toute la surface du globe, en des régions où la saison favorable à la production des atmosphériques ne coïncide pas avec l'été africain. La comparaison des courbes de Paris, Tunis, Rabat et Tamanrasset montre la grande similitude d'allure de la variation diurne, même en des stations éloignées ; une étude détaillée fait cependant apparaître quelques phénomènes particuliers : à Rabat, sur 27 kc/s, les atmosphériques ont peu d'activité dans le début de l'après-midi mais un maximum s'annonce en fin de journée, en parfaite coïncidence avec la fin du maximum d'après-midi à Paris ou à Tunis ; on peut en conclure que ce maximum d'après-midi, dans sa presque totalité, n'a pas une origine africaine ; cette origine doit se situer plus à l'est puisque les sources n'atteignent pas Rabat. L'influence du parcours maritime qui favorise la propagation est nettement démontrée dans le cas d'orages qui éclatent à Rabat et qui perturbent les courbes de Paris mais non celles de Tunis ou Tamanrasset. Des perfectionnements doivent encore être apportés à la technique des enregistrements, en particulier quant à la méthode d'étalonnage du seuil de fonctionnement des relais. On pourra alors donner aux courbes de la variation diurne des atmosphériques une interprétation météorologique beaucoup plus complète et précise.

Nº 60. — **Etude des courbes d'enregistrement d'atmosphériques au Scoresby Sund,** par R. Bureau.

Nº 61. — **On the adoption of a criterion for rating broadcast antennae according to the proportion of the radiated energy which is confined to small angles to the horizontal,** by Lieut. Col. W. A. Steel, Commissioner, Canadian Radio Broadcasting Commission. — (Full text).

In radio broadcasting the advantages of using transmitting antennae which are able to radiate most of their energy at small angles to the horizontal plane, are well known. Not only is the daytime range of the station, for equal radiated power, increased in this way, but also the objectionable distortion, occurring at night due to interference between the horizontal radiation and the sky radiation reflected back to earth, will begin at points more remote from the transmitter.

The above mentioned variation in the day range by alteration of the vertical plane polar radiation pattern demands a consideration of that pattern when attempting to use attenuation formulae to predict ranges of proposed stations over ground of known characteristics. Most such formulae neglect this as they assume a type of antenna which was practically always used up to a few years ago, namely, that in which the downlead was less than one-quarter wavelength. Some works on attenuation do consider the pattern but, owing to the lack of any recognised criterion, there is no standard method used to introduce this characteristic.

Accordingly, as an introduction to the discussion, it is proposed to adopt as the base the unattenuated field strength at unit distance in the horizontal plane from a vertical radiator one quarter of a wavelength in height radiating unit power. Let this field strength be « a » units. Then the « horizontal radiation factor » of an antenna giving a field strength of « b » units at unit distance for unit power radiated may be defined as equal to « b/a » units.

N° 62. — **Interaction of radio-waves,** by B. VAN DER POL and J. VAN DER MARK (1).

This note describes a new phenomenon in wave propagation which may have important consequences both in the scientific and technical radio field.

The phenomenon is the following. When a broadcasting receiving set is tuned to a radio station (here called « the wanted station »), sometimes at night the modulation of another powerful transmitter, whose frequency bears no simple relation to that of the wanted station, this frequency neither being close to that of the wanted station, is heard in the receiver as a background on the program of the wanted station. When the modulation of the wanted station is zero, the program of the unwanted station is occasionally so loud that the unwanted program can easily be recognised.

The phenomenon was first described by A. G. Butt (2) and B. D. H. Tellegen (3). The phenomenon was, at the authors' request, confirmed by Braillard, Ashbridge, Gutton, Schwaiger. About 50 different occasions are quoted where the phenomenon has been observed by different observers.

A careful analysis of all the above cases showed us that the phenomenon only occurs when the great circle joining the wanted station and the point of observation passes the unwanted station at a distance not greater than 250 to 300 km., which fact confirms the view that the phenomenon has its origin in the ionosphere, the more so because it only occurs at night.

We were therefore lead to consider the phenomenon as a non linear effect present in the ionosphere. It may therefore be expected to be more pronounced the stronger the field of the unwanted station in the ionosphere and therefore the larger the excursions of the electrons there. The effect will, according to this view, also be stronger the lower the frequency of the unwanted station. This is confirmed by the fact that all cases so far observed relate to interfering stations of high power only and relatively long wavelength, the shortest wavelength of the interfering station Praha (n = 638 kc/s). According to this point of view the waves of the unwanted station, in order to produce the effect, must not only travel through the ionosphere at the same geographical region, but also affect the ionosphere at the same geographical region, but also affect the ionosphere at the proper level at which the wanted signal travels. This may be the explanation why so far no cases have been observed with interfering waves longer than ca. 2000 *metres.*

A series of measurements of special transmissions by *Luxembourg* (230 kc/s) and *Beromünster* (556 kc/s) is described and it follows that this « cross modulation » effect caused by the Luxembourg transmitter on the Beromünster wave is a function of the modulation frequency of the interfering station (Luxembourg). The following average modulation depth observed at *Eindhoven* of the originally unmodulated Beromünster wave caused by a 80 % modulated wave emitted by Luxembourg was observed :

7,5 %	for a modulation	frequency of	100 c/s
3,7 %	»	»	200 c/s
3,3 %	»	»	400 c/s
1,2 %	»	»	800 c/s

the highest *momentary* maximum modulation depth of the, originally, unmodulated Beromünster wave observed being 12 % for a modulation frequency of 100 c/s.

The effect may either be explained on a *non-linear* basis, the presence of the strong unwanted emitter causing the apparent conductivity of the ionosphere to change so that the wanted wave travels through a modified medium, or by a *Doppler* effect, the radiation of the unwanted wave lifting periodically the ionosphere so that the wanted wave is reflected by a vibrating mirror. Further experiments are necessary in order to explain the phenomenon fully.

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(1) *Tijdschrift van het Ned. Radio Genootschap,* 1935.
(2) *World Radio,* Ap. 28th, 1933.
(3) *Nature,* June, 10th, 1933.

N° 63. — **Application de la mécanique non linéaire à quelques problèmes de la radiotechnique moderne,** par le Prof. Dr. N. Kryloff, et le Dr. N. Bogoliùboff.

Le rapport présenté contient sous forme condensée, l'énumération de résultats récents obtenus par les auteurs dans le domaine de la *Mécanique non-linéaire* et se rapportant aux sujets suivants :

1. Elaboration d'un procédé mathématique pour l'obtention des équations de première approximation relatives à des systèmes auto-périodiques (capables de produire des oscillations propres) du type de Thomson. Principe de la moyenne.

2. Quelques théorèmes par les auteurs, établissant la correspondance entre les propriétés de quasi-périodicité des solutions exactes et celles de leurs premières approximations.

3. Critères de l'existence et de la stabilité des solutions quasi-périodiques des équations différentielles régissant les oscillations des systèmes auto-périodiques. Zones fondamentales et secondaires de la synchronisation. Régimes synchrones et asynchrones des oscillations. Ordre de grandeur de l'erreur commise en s'arrêtant à la première approximation.

4. Possibilité d'obtenir des équations de première approximation à l'aide de la règle générale suivante : *on remplace d'une manière convenable, les circuits non linéaires par des impédances équivalentes qui dépendent en général de l'amplitude* α *et quelquefois (par ex. dans le cas de la résonance) de la phase* φ *de l'oscillation. Cela fait, on trouve, à l'aide des calculs habituels, le décrément* $\delta = \delta\,(\alpha, \varphi)$ *et la fréquence propre* du système ainsi rendu linéaire. L'expression approchée pour l'oscillation sera alors $\alpha = \alpha \sin .\, (\omega_0 t + \varphi)$, où α et φ vérifient les équations cherchées en première approximation :

$$\frac{d\,\alpha}{dt} = -\,\delta\,(\alpha, \varphi)\,\alpha \quad ; \quad \frac{d\,\varphi}{dt} = \omega\,(\alpha - \varphi) - \omega_0$$

dans lesquelles dans le cas de la résonance, on prend ω_0 égal à la fréquence synchrone et dans le cas de non-résonance, on calcule ω_0 au moyen de la formule de Thomson, en négligeant les corrections provenant des résistances des circuits et des circuits linéaires considérés.

5. Application de la méthode des impédances équivalentes pour l'étude du fonctionnement (comme générateur) d'un circuit oscillant contenant du fer et une capacité variable périodiquement (rôle stabilisateur de la non-linéarité due au fer). Application de la même méthode à l'étude du fonctionnement de l'oscillateur à triode en état de résonance de démultiplication.

6. Quelques considérations sur les possibilités d'emploi pratique des oscillateurs réglés à la résonance de démultiplication (filtres non-linéaires, amplificateurs de puissance, etc) (¹).

N° 64. — **A critical resume upon high-frequency bridge networks with special reference to high-frequency measurements on dielectrics,** by T. Iorwerth Jones, M. Sc., National Physical Laboratory (²).

The report is a review of most of the methods employed for the measurement of the permittivity and power factor of insulating materials at radio frequencies. It deals in greater detail with bridge methods and discusses the networks and the operating conditions which have been advanced from time to time.

Stress is laid on the fact that the success of the methods depends upon the apparatus which is employed and upon the disposition of the circuits. It is recognised that at high frequencies special considerations determine the design of suitable coils and the type and degree of screening which is adopted. The principles governing the application of screens are discussed. One section describes the high-frequency generators which various investigators have employed and the types of detectors which have proved satisfactory.

(¹) Le rapport complet sera publié dans l'*Onde Electrique*.

(²) Technical Report, Reference L/T56, published by the British Electrical and Allied Industries Research Association, 15, Savoy Street. London, W. C. 2.

Precision measurements of power factor are essentially dependent upon standards of capacitance and resistance. A survey is made of the available resources in these directions. A unique advantage offered by bridge methods is emphasised, namely, their ability to cope with three-terminal apparatus of which an electrode system incorporating a guard-ring is an important case, which, handled judiciously, can give enhanced accuracy. The earthing devices which need to be introduced to deal with such cases are discussed together with the desirability for the replacement of the earth capacitances of the electrodes, in certain cases, when a standard air condenser is substituted for the test condenser in the ordinary way.

Finally, a few electrode systems are described and suggestions are advanced for the future development of bridge methods at radio frequencies.

N° 65. — **Note sur la propagation des ondes de 18,68 et 31,19 mètres sur le parcours Saïgon-Paris.**

Cette étude décrit les résultats d'observations d'échos pour des signaux captés dans l'exploitation du Service de la T. S. F. français. A certaines époques de l'hiver, ces échos durent environ 1 1/2 heure et présentent un retard de 0,07 sec.

N° 66. — **Note sur la propagation des ondes de 24,56 et 33 mètres entre Paris et Alger.**

Cette étude décrit un phénomène d'évanouissement (fading) sélectif observé sur la communication téléphonique Paris-Alger. Ce fading sélectif affecte successivement les diverses fréquences de la bande modulée.

N° 67. — **Relations entre les phénomènes de propagation et les échos et les phénomènes de la géophysique** par K. W. WAGNER et K. FRÄNZ.

A Tromsö (en Norvège) de décembre 1932 à octobre 1934, l'expédition radioscientifique envoyée par la « Gesellschaft zür Forderung des Funkwesens » (Société pour l'Etude de la Radioélectricité) a découvert certaines relations de dépendance entre les phénomènes d'échos et de propagation et les phénomènes de la géophysique. Ces relations sont exposées sommairement dans ce qui suit.

La station d'observation fut installée en décembre 1932 à l'Observatoire d'Aurore Boréale à Tromsö par MM. le Dr. Ing. K.Kreielsheimer et l'Ingénieur W. Stoffregen, qui firent également les observations; d'avril à octobre 1934, M. K. Fränz remplaça M. Kreielsheimer. Du début de janvier jusqu'à la fin août 1933, il y eut collaboration entre les expéditions allemande et anglaise à Tromsö.

Des investigations furent faites concernant l'ionosphère par la méthode des échos, ainsi que des observations d'intensité de champ et d'évanouissement de stations européennes de radiodiffusion.

En plus des allures saisonnières et diurnes bien connues de ces phénomènes, on constata à Tromsö, qui se trouve dans la zone des aurores les plus fréquentes, une influence particulièrement profonde des perturbations magnétiques accidentelles.

En ce qui concerne le comportement régulier de la zone F de l'ionosphère pour la fréquence 2 Mgc. (150 mètres) on a pu affirmer qu'il existait une réelle différence entre les phénomènes appelés « Aufgange » et ceux appelés « untergangsphënomen ».

On signifie par là que, pour des augmentations ou des diminutions lentes de la concentration en ions, et pour une fréquence donnée, la couche est encore réfléchissante pour de très faibles vitesses de signal.

La régularité des « aufgange » pour 2 mégacycles est remarquable et correspond à un courbe qui présente son maximum quand le soleil est à 7° 30′ sous l'horizon.

Les « untergange » ont une dispersion beaucoup plus considérable que les « aufgange ». En outre, les deux phénomènes sont asymétriques par rapport au midi vrai (11 h. 44'). Cela est compréhensible en tenant compte de ce que le « untergange » résulte non seulement de l'occultation du rayonnement ionisant, mais aussi de la recombinaison et de la dispersion des ions. Il est intéressant de noter qu'en outre du « untergange » normal de l'après-midi, une série de ces phénomènes fut observée très tôt le matin.

Tenant compte du fait que sur 16 phénomènes analogues, aucun « aufgange » correspondant ne fut observé, on a pu conclure que cette ionisation était provoquée par une cause subite. Effectivement, les échos correspondants commençaient à des temps très irréguliers.

L'allure normale des évanouissements des stations européennes répond à une périodicité annuelle sinusoïdale. La première observation se passe au solstice d'hiver (21 décembre) à 15 heures. La dernière au solstice d'été (21 juin) à 24 heures. Au printemps et en été, il ne fut possible d'entendre aucune station européenne à midi, d'où il résulte avec certitude qu'aucune onde directe n'y parvient.

Au cours de l'après-midi, l'intensité de champ monte progressivement au-dessus du niveau des perturbations et quelques heures plus tard commencent les variations d'intensité.

Jusqu'à ce moment, le champ est polarisé, après quoi débutent les variations sur place de polarisation.

L'apparition du phénomène ne peut donc s'expliquer par l'interférence d'une onde linéaire directe et d'une onde réfléchie elliptique.

En même temps que des perturbations magnétiques apparaissent régulièrement, de grandes variations de l'ionosphère par rapport à son état normal, celui-ci étant défini comme l'état normal connu aux latitudes moyennes.

La caractéristique est l'exemple de l'apparition rapide d'un haut degré d'ionisation de la couche E, lors des perturbations magnétiques du soir.

Comme exemple typique, deux enregistrements d'échos sur 75 et 72,5 m. ont été choisis.

L'évanouissement normal pour 75 m. a lieu 11 minutes après l'heure repère, pour 72, 5 m., 6,2 minutes plus tôt. Brusquement, après 15 minutes (exactement 14,2 minutes en tenant compte de l'exactitude des lectures), la région E devient réfléchissante pour les deux ondes.

Par contre, par les jours calmes, pendant les maxima d'ionisation de la couche E, cette dernière ne réfléchit pas l'onde de 75 mètres.

Dans la couche E s'abaisse également la hauteur où s'observe le plus fréquemment les aurores boréales.

Il est typique d'observer combien la région F est sélective par rapport à de faibles différences de fréquence ; par exemple, on observe pour les deux fréquences précitées, des différences apparentes de hauteur dans le rapport de 1 à 2 et des décalages dans le temps des phénomènes de « aufgang » et de « untergang » de plus de 30 minutes et cependant que l'ionisation anormalement élevée de la couche E, pour les deux ondes, et dans les limites de la précision de lecture, apparaissait en même temps et à la même hauteur.

Ces deux phénomènes s'accordent bien avec l'explication donnée par Appleton, Naismith et Builder et selon laquelle l'ionisation résulterait du rayonnement corpusculaire de l'aurore boréale. Les jours de forte ionisation de la couche E furent presqu'exclusivement des jours de fortes perturbations magnétiques et furent aussi des jours où les échos de l'onde de 75 m. pour la couche E durèrent plus longtemps que pour la couche F.

De même les variations d'intensité (fading) montrèrent une autre allure pendant les jours troublés que pendant les autres. Leur apparition était retardée ou ne se produisait pas. Pendant ces jours, le champ était polarisé linéairement comme aux jours de juin.

Le pouvoir réfléchissant de l'ionosphère diminuait pour des ionisations plus fortes. Pendant l'heure de midi en été et aussi pendant les perturbations magnétiques, il fut souvent impossible d'obtenir le moindre écho.

Pendant les perturbations magnétiques, les échos observés lors d'une réflection à la perpendiculaire disparaissaient presque complètement et l'intensité de champ des stations de radiodiffusion diminuait.

Cependant, une seule fois au cours de 20 observations pendant une aurore boréale, la réception de ces stations fut totalement impossible.

La forme extraordinairement agitée et irrégulière de la lumière boréale laisse soupçonner que l'ionisation créée par le rayonnement corpusculaire est aussi très irrégulière ; le pouvoir réfléchissant de l'ionosphère pour des rayons incidents normaux doit donc être beaucoup plus faible que pour l'incidence rasante des ondes de la radiodiffusion.

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